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FEBRUARY 1956 **VOL. LI. NO. 2**

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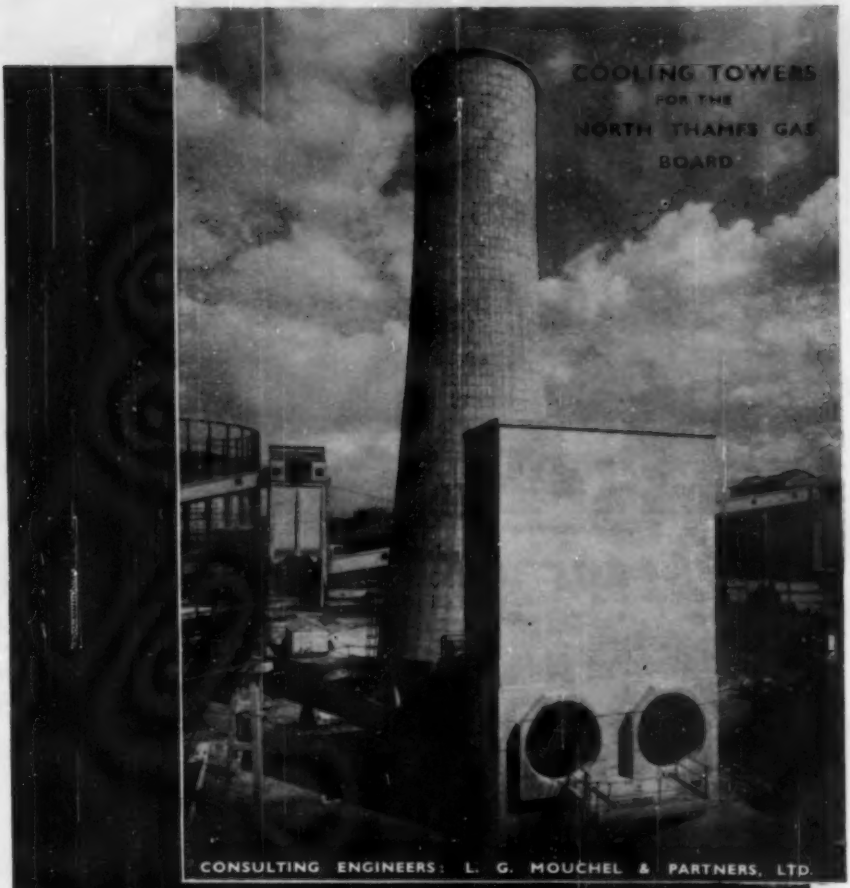

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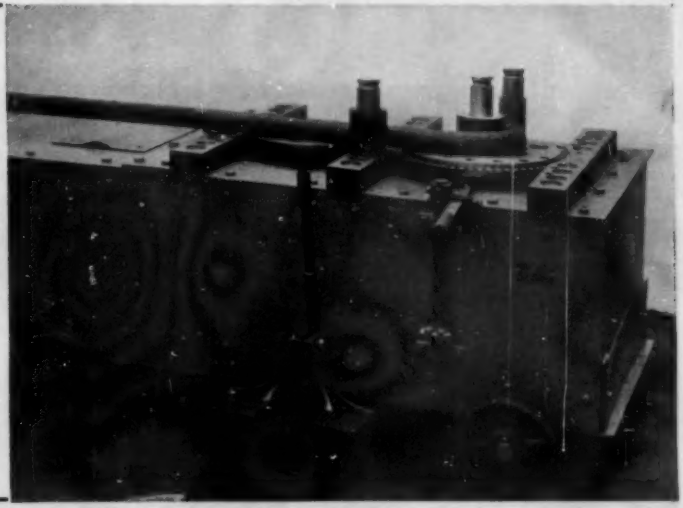

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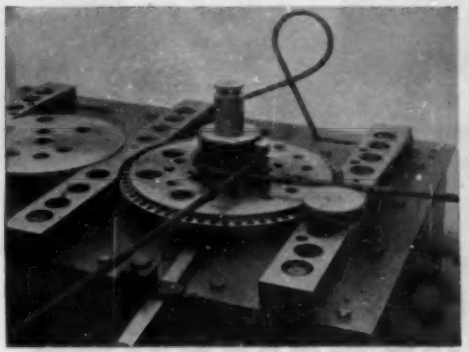

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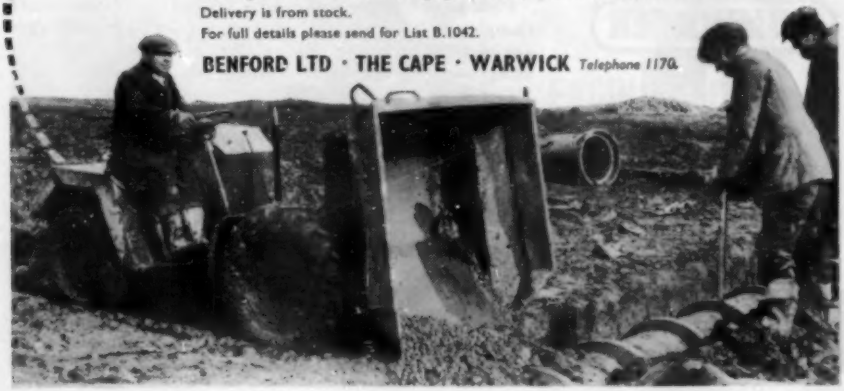

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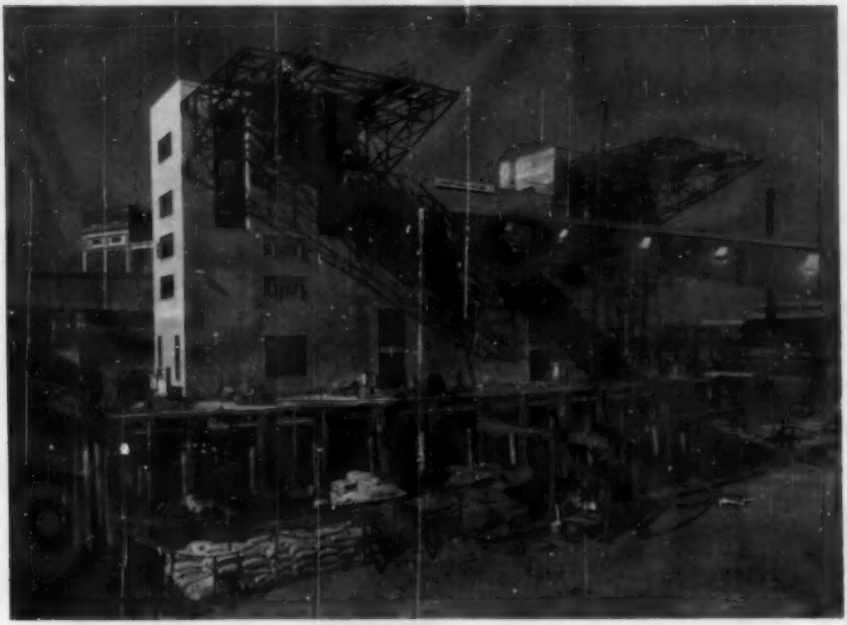

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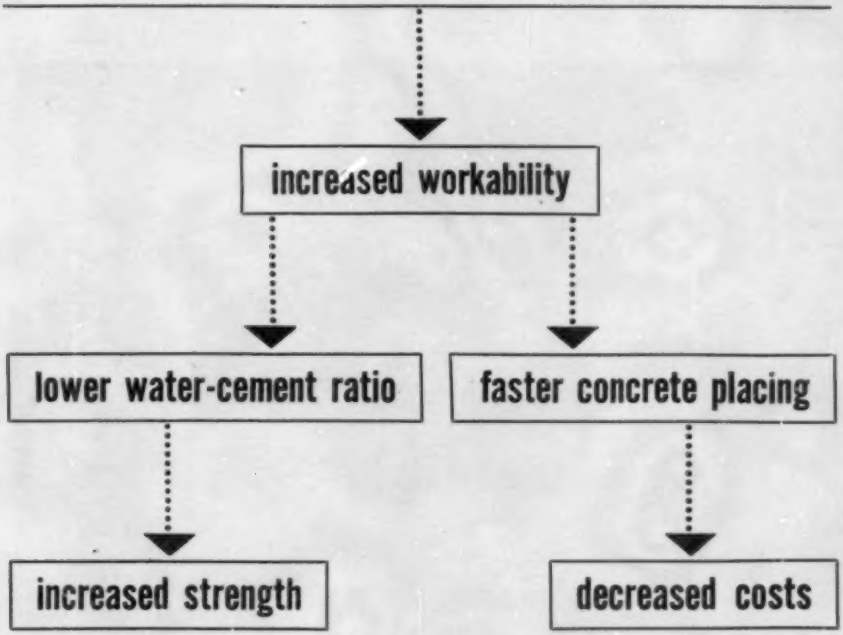

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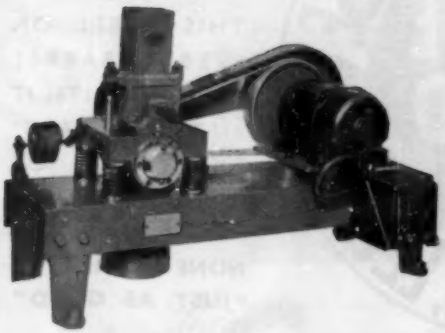

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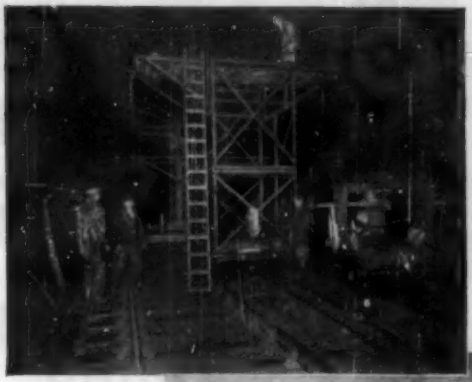

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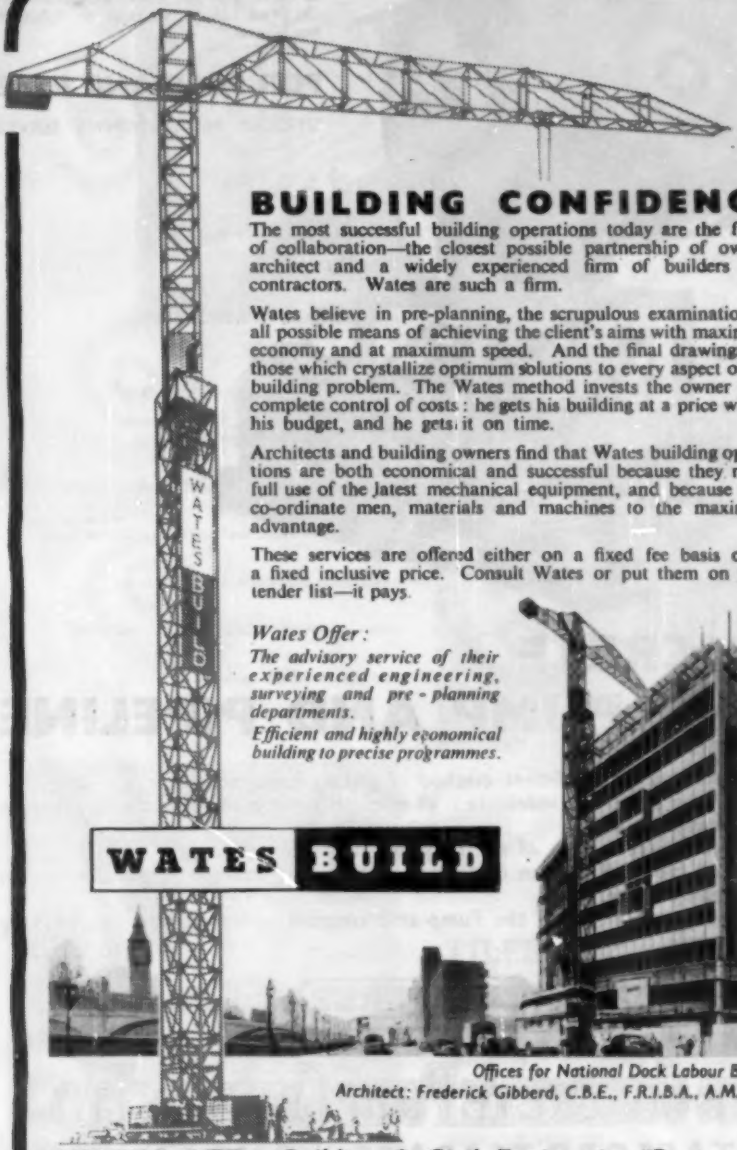

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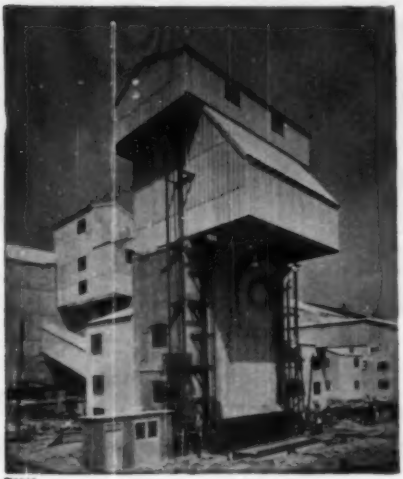

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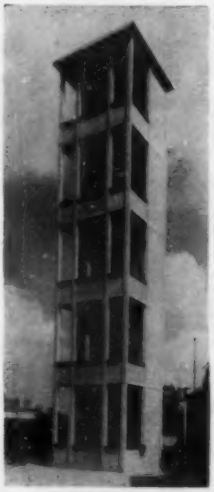

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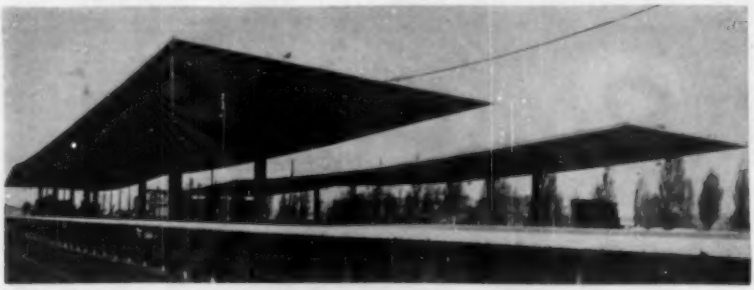

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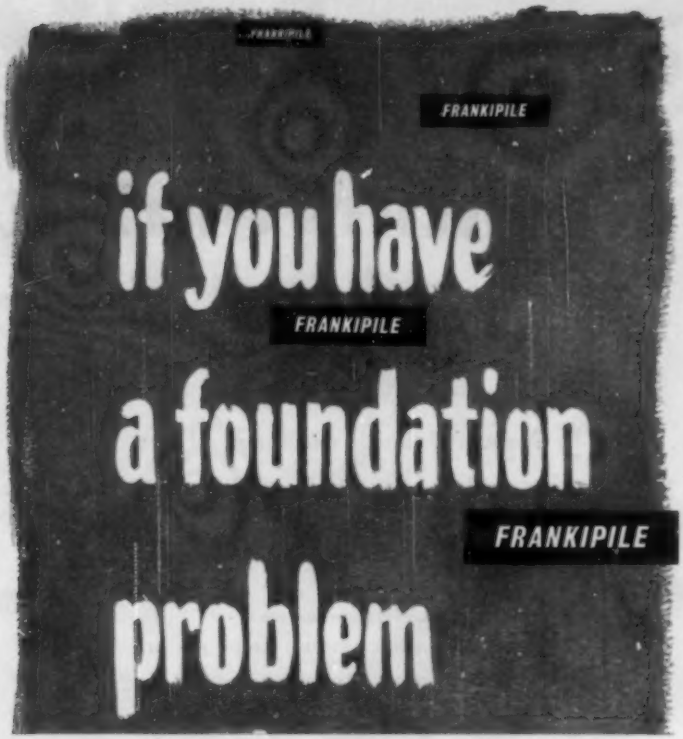

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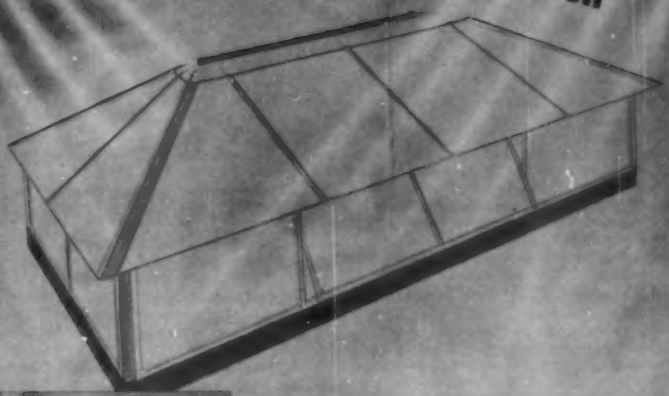

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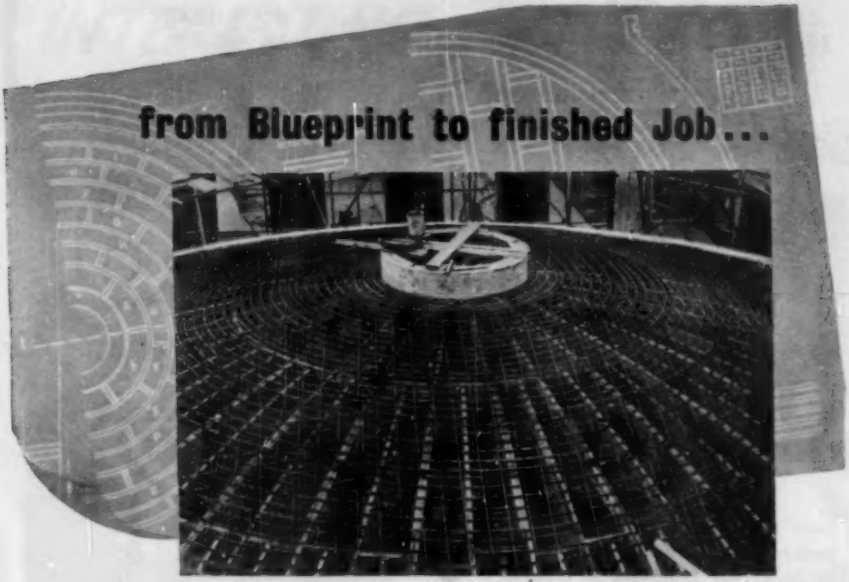

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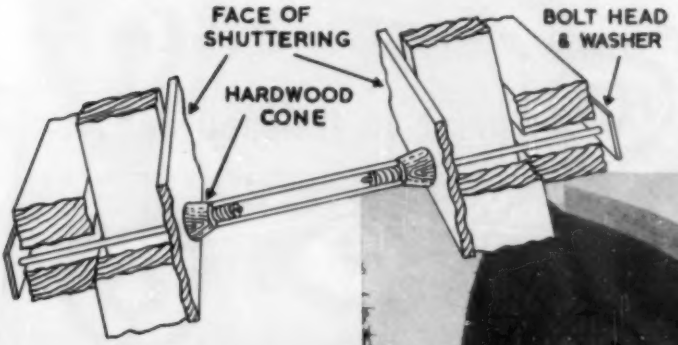

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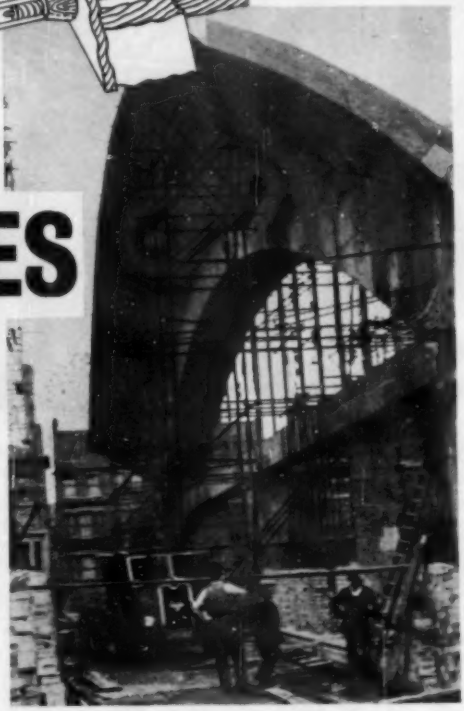

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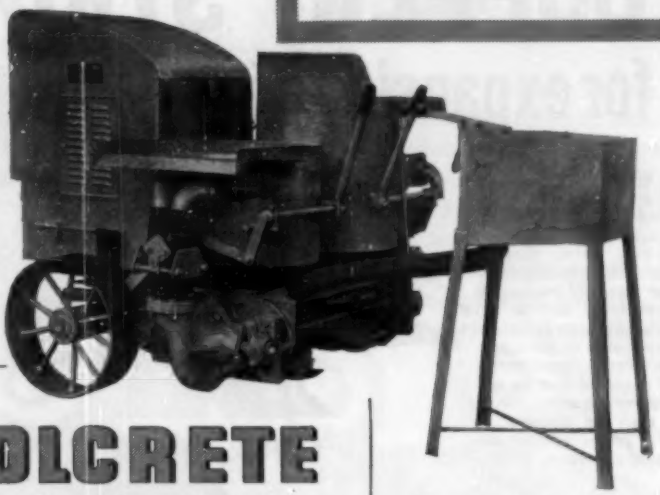

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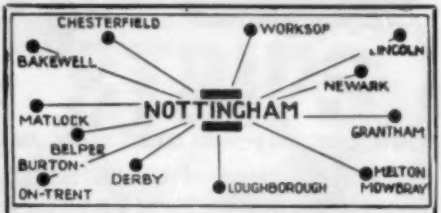

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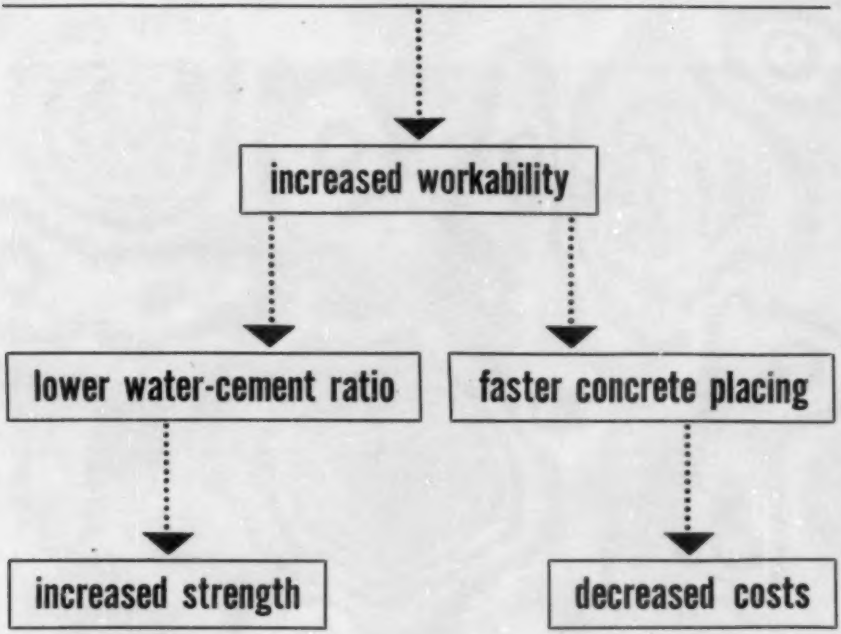

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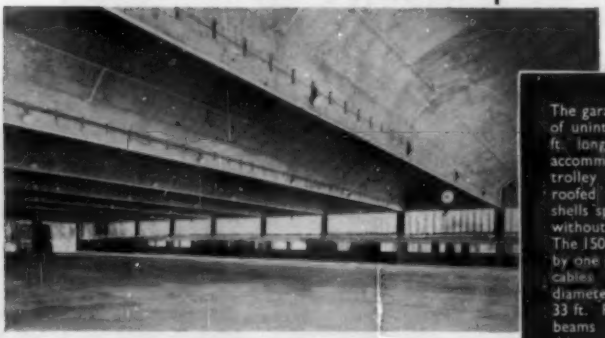

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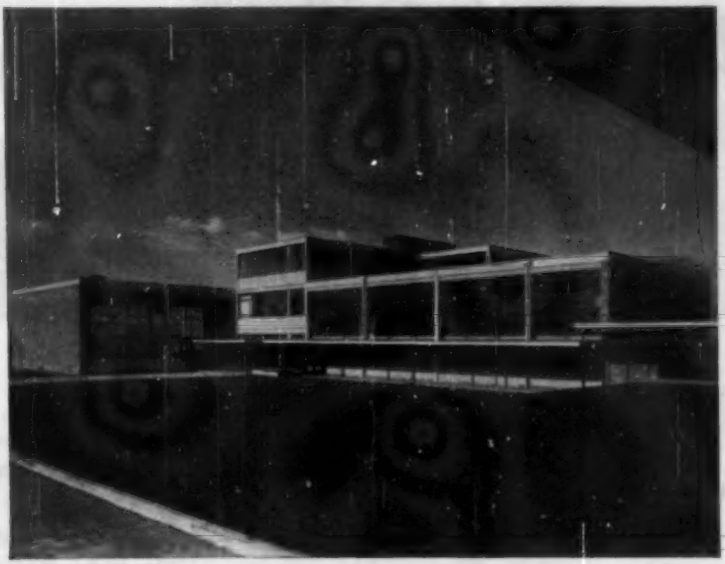

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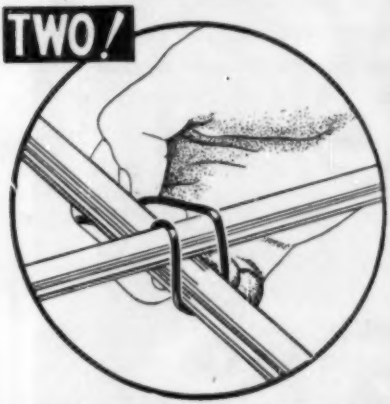

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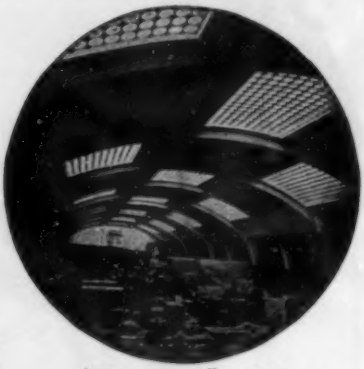

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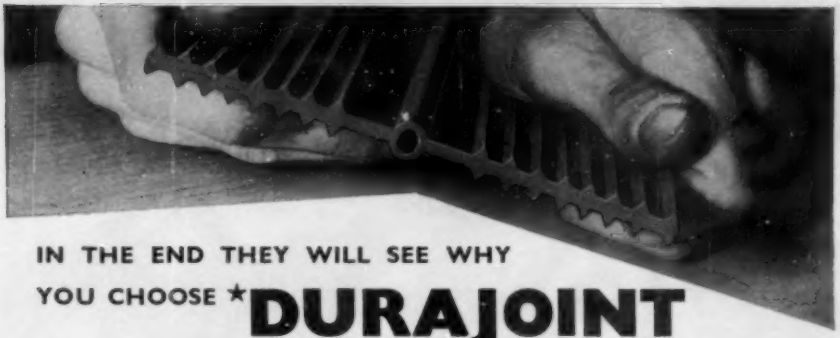

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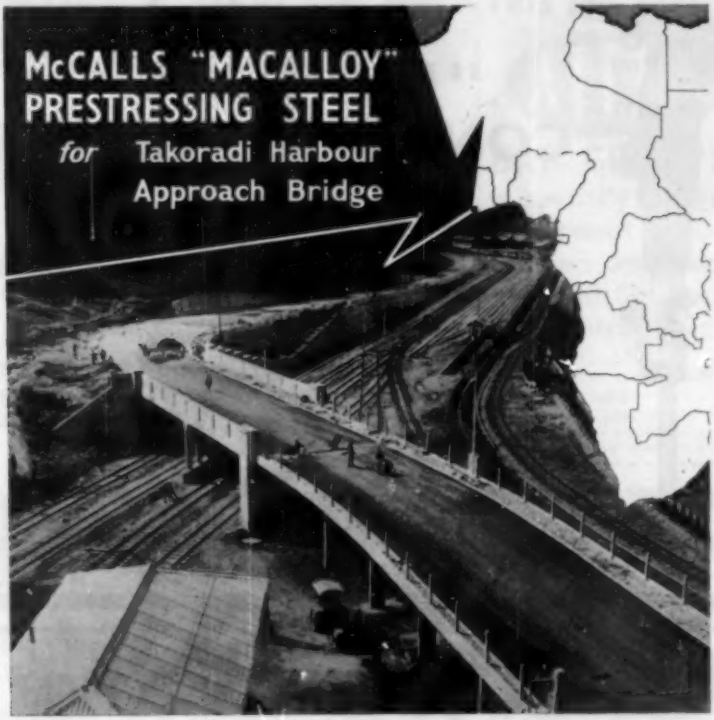

The photograph shows a prestressed concrete road bridge over the railway yard at Takoradi Harbour extensions, Gold Coast Colony. Designed by Rendel, Palmer and Tritton, Consulting Engineers to the Gold Coast Railways and Harbours Administration, and making use of the Lee-McCall system, the bridge was constructed by Taylor Woodrow (West Africa) Ltd. The precast beams of the bridge are of 44 ft. span, each prestressed with 3–1⅛″ diameter Macalloy post-tensioned bars.

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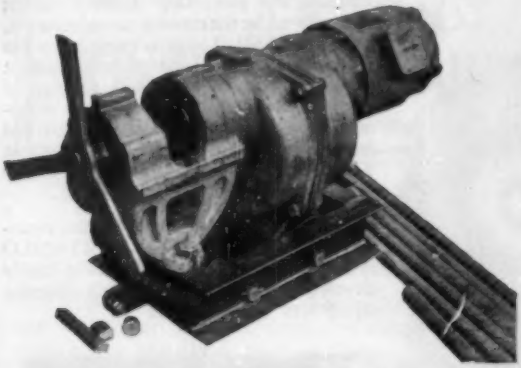

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Volume LI, No. 2. LONDON, FEBRUARY, 1956.

EDITORIAL NOTES

Standards.

STANDARDS appear to have originated in Great Britain in the year 1901 when the Institution of Civil Engineers suggested that the number of different steel sections be restricted, and as a result the number of sizes of structural steel sections was reduced from 175 to 113 and of tramway rails from seventy-five to five, with a consequent saving of about a million pounds a year in production costs. Also early in this century much useful work was done in the standardisation of sizes of screws and bolts. All this work was done by voluntary bodies formed and financed by the industries concerned with the object of reducing costs. The standards were concerned with dimensions only, and did not attempt to standardise quality. When the advantages of the standardisation of sizes were more generally appreciated, standard sizes were adopted by other industries, to the benefit of manufacturers and users alike. With the formation of the British Standards Institution, three important changes have taken place. First, the cost of producing standards was financed last year by the Government to the extent of £120,000 a year out of a total expenditure of £369,000 by the Institution; the remainder of the expenditure was paid for by donations and subscriptions of firms and individuals and by the sale of standards. The second important change is that many standards now prescribe the quality and other properties of products as well as dimensions, and the third is that only a minority of new standards appear to be initiated by the industries concerned. According to a report * recently issued, of 111 proposals for new standards considered by the Institution during the six months to May, 1955, only six were requested directly by manufacturers and five by trade associations, and seventeen came from professional and research associations. Of the remaining proposals for new standards, 39 came from Government departments and local authorities and 43 from committees of the Institution. The fact that so many of these requests for standards came from Government departments and local authorities is perhaps in accordance with the tendency of a bureaucracy to take the easy course of accepting what someone else has decided is suitable. It is much easier merely to insert in a specification the words "according to British Standard" than to select an article or a product after comparing the prices and qualities offered by different

* "The British Standards Institution." "Standards in Industry." Issued by Political and Economic Planning. Price 2s. 6d. each.

makers. A British Standard quality will always be one of mediocrity because it must be such that most if not all manufacturers can produce it, and it will generally be revised only at long intervals. At a time when Government departments, local authorities, and nationalised industries are the largest buyers of many products for which there are British Standards, there is little incentive for manufacturers to produce goods of better quality when by far the bulk of their orders are for goods of British Standard quality.

One of the reports referred to states that standardisation can bring with it some serious problems. An example is to be seen in the case of the British Standard for Portland cement. All cement made in Great Britain has properties in excess of those required by the British Standard, and the products of some factories with sources of exceptionally good raw materials are far in advance of the standard. The result is that cements from different works, and sometimes from the same works, differ in quality although they all exceed the requirements of the Standard. This is quite unavoidable, but it often leads to unreasonable demands from users. For example, cement may be specified and ordered to be in accordance with the British Standard, and when it is delivered it is found that it is all of better quality than is called for by the Standard, and that some consignments have exceptional rapid-hardening properties. Although the user is getting with every consignment better value than he is strictly entitled to, it is perhaps natural that he should demand that every consignment be as good as the best. Due to the nature of the raw materials available the cement produced at some works is consistently of better quality than that made at other works, and as this has become more generally known it has happened that users have insisted on receiving cement from a particular works far in excess of its capacity. In the present state of knowledge variation in the properties of cement is unavoidable, and is common experience throughout the world. A standard for cement can therefore stipulate minimum requirements only, and not the uniformity that is denoted by the word standard.

British Standards can also be standards of expediency or even of inferiority, as happened during the war when standards were issued in order to permit the use of substitute materials. Such a case is the recent revision of the British Standard for concrete aggregates, which permits the use of sands that were not previously permitted, and which would have been rejected by many engineers. The reason for this lowering of the standard is the great demand for aggregates and the desire to avoid the scarcity that would probably have arisen had the previous quality been insisted upon.

There are now about 3000 standards in existence relating to all sorts of products in all sorts of industries. Some of these are useful, according to the P.E.P. report some are ignored, and some are unnecessary. But there is no doubt that thousands more will be issued to satisfy the demand from those who are unable to, or do not wish to, select a product on a comparison of price and quality and ultimate value. As one of these reports states, " Any long-established standard produces its own vested interests anxious to prevent any alterations, and . . . the revision of an existing standard may provoke the resistance of manufacturers tooled to produce in accordance with the old standard," that is, insistence on standardising a product may hinder the production of a better one.

Analysis of Frames with Two Gables.

By V. A. MORGAN, M.Eng., A.M.Inst.C.E.

Side Load Acting at Eaves Level on External Column.

Fig. 1(*c*) is equivalent to the sum of *Figs.* 1(*a*) and 1(*b*). In the previous article * general solutions for moments and thrusts were given for single-gable frames with columns of stiffnesses K_1 and K_2. These solutions can be applied to double-gable frames [*Fig.* 1(*c*)]. By substituting $\frac{1}{2}K_2$ for K_2 and $\frac{1}{2}P$ for P in equations (5) to (10) in the previous article the solution for the frame shown in *Fig.* 1(*a*) may be obtained and added to the solution for the frame shown in *Fig.* 1(*b*); this will give the solution of *Fig.* 1(*c*).

SOLUTION TO *Fig.* 1(*b*). As the opposing forces and moments on the central column are equal there is no rotation of this column, and the frame may be considered as fixed at C. The independent frames ABC and A_1B_1C are similarly acted upon by opposing loads of $\frac{1}{2}P$ at the eaves.

The stiffness ratios and carry-over factors are the same as those in the column and rafter frames already dealt with.

Fixing moments C_1 are caused by Δ_1 at the top of the column and at the base due to load $\frac{1}{2}P$, and fixing moments D_1 are caused in the rafters at B, C, and B_1.

Then $C_1 = \dfrac{6EK_1\Delta_1}{h}$ and $D_1 = \dfrac{3EK_o\Delta_1}{r} = \dfrac{hC_1}{2rK_1}$ since $K_o = 1$. Also the stiffness ratios of joint B with the base of the column and the foot of the rafter (fixed) are $8K_1$ and 7.

$D_1 - C_1 = \dfrac{C_1(h - 2rK_1)}{2rK_1}$ and $H_o = -\dfrac{3EK_o\Delta_1}{2r^2} = -\dfrac{hC_1}{4r^2K_1}$, the negative sign indicating inward thrust. Thus, distributing moments as shown in *Table* I, by summation, and substituting for D_1,

$$M_{AB} = \frac{C_1(4rK_1 + 7r + 2h)}{r(8K_1 + 7)}. \qquad M_{BA} = \frac{C_1\,(4h + 7r)}{r(8K_1 + 7)} = -M_{BC}.$$

$$M_{CB} = \frac{C_1(3h + rK_1 + 4hK_1)}{rK_1(8K_1 + 7)}.$$

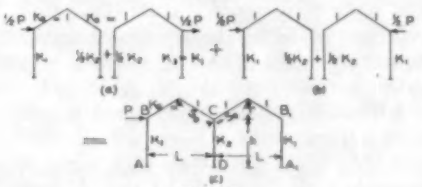


Fig. 1.

TABLE I.

A CARRY OVER ½	8K₁ B 7	CARRY OVER −½ C
C_1	C_1	$-D_1$ $\quad D_1$
$\dfrac{4K_1(D_1 - C_1)}{8K_1 + 7}$	$\dfrac{8K_1(D_1 - C_1)}{8K_1 + 7}$	$\dfrac{7(D_1 - C_1)}{8K_1 + 7}$ $\quad -\dfrac{(D_1 - C_1)}{8K_1 + 7}$

* See this journal for July, 1955.

$$H_{rafter} = H_o + \frac{3}{4r}(M_{BC} - M_{CB})$$

$$= -\frac{C_1}{4r^2}\left\{\frac{h}{K_1} + \frac{3(4h + 7r)}{8K_1 + 7} + \frac{(9h + 3rK_1 + 12hK_1)}{rK_1(8K_1 + 7)}\right\}$$

where the negative sign indicates inward thrust and the actual value is

$$\frac{(8hK_1 + 6rK_1 + 4h)}{r^2K_1(8K_1 + 7)}C_1.$$

$$H_{column} = \frac{M_{AB} + M_{BA}}{h} = \frac{(4rK_1 + 14r + 6h)}{hr(8K_1 + 7)}C_1.$$

Then $H_{rafter} + H_{column} = \frac{P}{2}$.

Therefore $$C_1 = \frac{r^2hK_1(8K_1 + 7)P}{2(4r^2K_1^2 + 14r^2K_1 + 12rhK_1 + 8h^2K_1 + 4h^2)}.$$

$$M_{BA} = \frac{rhK_1(4h + 7r)P}{Den}, \text{ where } Den \text{ is the denominator of } C_1.$$

$$M_{AB} = \frac{rhK_1(4rK_1 + 7r + 2h)}{Den}P. \qquad M_{CB} = \frac{rh(3h + rK_1 + 4hK_1)}{Den}P.$$

$$H_1 = \frac{(4rK_1 + 14r + 6h)rK_1P}{Den}. \qquad H_{rafter} = \frac{(8hK_1 + 6rK_1 + 4h)hP}{Den}.$$

Substituting $\frac{1}{2}K_2$ and $\frac{1}{2}P$ for K_2 and P in equations (5) to (10) of the previous article dealing with single gable frames and adding to *Fig.* 1(*b*) the solutions just obtained, the final general solutions are:

$$\left.\begin{matrix} M_{AB} \\ M_{A,B_1} \end{matrix}\right\} \times \frac{4}{hP}$$

$$= \frac{1}{\beta_2}\left\{r(\alpha_1 - 2K_1K_2 + 7K_1 + 18) + h(12K_1 + K_2 + 24) + \frac{h^2}{rK_2}(2\alpha_1 + 3K_2 - 6K_1 - 6)\right\}$$

$$\pm \left(\frac{4K_1r + 7r + 2h}{2K_1r + 7r + 6h + \dfrac{4h^2}{r} + \dfrac{2h^2}{rK_1}}\right) . \quad (1)$$

$$\left.\begin{matrix} M_{BA} \\ M_{B_1A_1} \end{matrix}\right\} \times \frac{4}{hP} = \frac{1}{\beta_2}\left\{r(3{\cdot}5K_2 + 24) + h(2K_2 + 30) + \frac{3h^2}{rK_2}(4K_2 + 2)\right\} \pm \left(\frac{7r + 4h}{Y}\right) . \quad (2)$$

$$\left.\begin{matrix} M_{CB} \\ M_{CB_1} \end{matrix}\right\} \times \frac{4}{hP} = -\frac{1}{\beta_2}\left\{h\left(9 - 2K_2 - 1{\cdot}5\frac{K_2}{K_1}\right) - 0{\cdot}5K_2r + \frac{3h^2}{rK_1}(4K_1 + 1)\right\},$$

$$\pm \left\{\frac{1}{Y}\left(4h + \frac{3h}{K_1} + r\right)\right\} . \quad (3)$$

$$M_{CD} \times \frac{2}{hP} = \frac{1}{\beta_2}\left\{h\left(9 - 2K_2 - 1{\cdot}5\frac{K_2}{K_1}\right) - 0{\cdot}5K_2r + \frac{3h^2}{rK_1}(4K_1 + 1)\right\} . \quad (4)$$

$$M_{DC} \times \frac{2}{hP} = \frac{1}{\beta_2}\left\{h\left(9 + 5K_2 + 1{\cdot}5\frac{K_2}{K_1}\right) + 0{\cdot}5K_2r + \frac{h^2}{rK_1}(\alpha_1 - 1{\cdot}5K_2 + 3K_1 - 3)\right\}. \quad (5)$$

where $\alpha_1 = 4K_1K_2 + 7K_1 + 3{\cdot}5K_2 + 6$, $Y = 2K_1r + 7r + 6h + \frac{4h^2}{r} + \frac{2h^2}{rK_1}$,

and $\beta_2 = r(\alpha_1 - 3K_1K_2 + 18) + 3h(K_2 + 2K_1 + 12)$

$$+ \frac{h^2}{2rK_2}\left(2\alpha_1 + \frac{K_2}{K_1}\alpha_1 + 30K_2 - \frac{1{\cdot}5K_2^2}{K_1} - 6K_1\right).$$

$$\frac{2C_2}{hP} = \frac{1}{\beta_2}\left\{1{\cdot}5K_2r + 3h\left(4K_2 + 1{\cdot}5\frac{K_2}{K_1} + 3\right) + \frac{h^2}{rK_1}(8K_1K_2 + 4K_2 + 8K_1 + 3)\right\} \quad . \quad (6)$$

$$\left.\begin{matrix}C_1\\C_2\end{matrix}\right\} \times \frac{4}{hP} = \frac{1}{\beta_2}\left\{r(4K_1K_2 + 3{\cdot}5K_2 + 28K_1 + 24) + 6h(4K_1 + 3)\right.$$

$$\left. + \frac{2h^2}{rK_2}(8K_1K_2 + 4K_2 + 8K_1 + 3)\right\} \pm \frac{1}{Y}(8K_1r + 7r) \quad . \quad (7)$$

These general formulæ are simple to apply. For example, take the case of a frame with the following properties: $K_1 = K_2 = K_0$; $h = S_0 = 14$ ft.; $r = 6$ ft.; $L_1 = L_2 = 24$ ft. = clear span. Substituting in equations (1) to (7) and for α_1, β_2, and Y, $\alpha_1 = 20{\cdot}5$, $\beta_2 = 2215$, and $Y = 334$.

$$\left.\begin{matrix}M_{AB}\\M_{A_1B_1}\end{matrix}\right\} = hP\left\{\frac{5473}{60 \times 443} \pm \frac{47}{668}\right\}. \qquad \left.\begin{matrix}M_{BA}\\M_{B_1A_1}\end{matrix}\right\} = hP \times \left\{\frac{3603}{6 \times 4430} \pm \frac{49}{668}\right\}$$

$$M_{CO} = \frac{1692hP}{13{,}290}.$$

$$M_{DC} = \frac{2522hP}{13{,}290}. \qquad \left.\begin{matrix}M_{CB}\\M_{CB_1}\end{matrix}\right\} = -\frac{846hP}{13{,}290} + \frac{13hP}{167}.$$

$$C_2 = \frac{1676hP}{6645}. \qquad \left.\begin{matrix}C_1\\C_2\end{matrix}\right\} = \left\{\frac{7343}{26{,}580} \pm \frac{45}{668}\right\}hP.$$

Therefore $\Delta_2 = \frac{C_2h}{6EK_2} = \frac{1676h^2P}{6 \times 6645EK}$.

$$\left.\begin{matrix}H_1\\H_2\end{matrix}\right\} = \frac{M_{AB} + M_{BA}}{h} = \left\{\frac{9076}{26{,}580} \pm \frac{24}{167}\right\}P. \qquad H_2 = \frac{M_{CD} + M_{DC}}{h} = \frac{4214P}{13{,}290}.$$

SIDE LOAD.—The force P acting at point C of the central column is equivalent to two loads of $\frac{1}{2}P$ acting as shown in *Figs.* 2 where the central column is divided into two parts, each of stiffness $\frac{1}{2}K_2$, to form two separate single frames. To calculate this case it is simpler to treat the right-hand frame of *Fig.* 2(*a*) acted upon by the side load $\frac{1}{2}P$ at the eaves. As the central column is composed of half columns, their combined stiffnesses being K_2, P will act at C. Substituting $\frac{1}{2}K_2$ for K_1 and K_1 for K_2 in equations (5) to (10) of the previous article dealing with single gable frames, and making M_{AB} into M_{CD} and M_{CD} into $2M_{BA}$, and as $2M_{BA} = 2M_{B_1A_1}$, etc.,

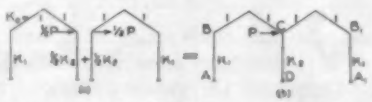


Fig. 2.

$$\frac{2\beta_3}{Ph} \times M_{DC} = r(2K_1K_2 + 7K_1 + 7K_2 + 24) + h(6K_2 + 2K_1 + 24) + \frac{h^2}{rK_1}(4K_1K_2 + 10K_1 + 2K_2 + 3) \quad . \quad . \quad (8)$$

$$\frac{2\beta_3}{Ph} \times M_{CD} \text{ or } -2M_{CB} \text{ or } -2M_{CB_1} = r(7K_1 + 24) + h(4K_1 + 30) + \frac{h^2}{rK_1}(12K_1 + 3) \quad . \quad (9)$$

$$\frac{4\beta_3}{Ph} \times M_{BA} \text{ or } M_{B_1A_1} = -rK_1 + h\left(9 - 4K_1 - \frac{6K_1}{K_2}\right) + \frac{3h^2}{rK_2}(4K_2 + 2) \quad . \quad (10)$$

$$\frac{4\beta_3}{Ph} \times M_{AB} \text{ or } M_{A_1B_1} = rK_1 + \left(10K_1 + 9 + \frac{6K_1}{K_2}\right)h + \frac{2h^2}{rK_2}(4K_1K_2 + 4K_1 + 5K_2 + 3) \quad . \quad . \quad (11)$$

$$\frac{4\beta_3}{Ph} \times C_1 \text{ or } C_3 = 3K_1r + 3h\left(8K_1 + \frac{6K_1}{K_2} + 3\right) + \frac{2h^2}{rK_2}(8K_1K_2 + 8K_1 + 4K_2 + 3) \quad . \quad . \quad (12)$$

$$\frac{2\beta C_3}{hP} = r(4K_1K_2 + 7K_1 + 14K_2 + 24) + 6h(2K_2 + 3) + \frac{h^2}{rK_1}(8K_1K_2 + 8K_1 + 4K_2 + 3) \quad . \quad . \quad (13)$$

$$\beta_3 = r(K_1K_2 + 3{\cdot}5K_2 + 7K_1 + 24) + h(6K_1 + 3K_2 + 36) + \frac{h^2}{rK_1}\left(4K_1^2 + \frac{4K_1^2}{K_2} + 2K_1K_2 + 22K_1 + \frac{6K_1}{K_2} + K_2 + 3\right) \quad . \quad . \quad (14)$$

$$\alpha_1 = 4K_1K_2 + 3{\cdot}5K_2 + 7K_1 + 6.$$

By substituting $K_1 = K_2$, etc., in these equations, the following values are obtained:

$$\left.\begin{matrix} M_{AB} \\ M_{A_1B_1} \end{matrix}\right\} = \frac{2102Ph}{13{,}290}, \quad \left.\begin{matrix} M_{BA} \\ M_{B_1A_1} \end{matrix}\right\} = \frac{852Ph}{13{,}290}, \quad M_{CD} = \frac{3456Ph}{13{,}290} = -2M_{CB} = -2M_{CB_1},$$

$$M_{DC} = \frac{3926Ph}{13{,}290}, \quad C_1 = C_3 = \frac{3352Ph}{13{,}290}, \quad C_2 = \frac{6650Ph}{13{,}290},$$

$$\left.\begin{matrix} H_1 \\ H_3 \end{matrix}\right\} = \frac{M_{AB} + M_{BA}}{h} = \frac{2954P}{13{,}290}, \quad H_2 = \frac{M_{CD} + M_{DC}}{h} = \frac{7382P}{13{,}290},$$

$$C_1 = \frac{6EK_1\Delta_1}{h}, \text{ so that } \Delta_1 = \frac{1676h^2}{6 \times 6645EK}.$$

Δ_1 is the deflection at B due to P acting at C, and Δ_2 is the deflection at C due to P acting at B; therefore, from Maxwell's Theorem of Reciprocal Deflections, $\Delta_1 = \Delta_2$. These and the values calculated for the loading shown in *Fig.* 1(*c*) are shown in *Figs.* 3(*b*) and 3(*a*) respectively.

The forces in a frame caused by side loads applied at the tops of the eaves and valley column may be used, as shown in the previous article, to balance forces caused by other types of loading. The following example (*Fig.* 4) demonstrates this.

Assume a uniformly-distributed load wL on the horizontal projection of each bay of the roof. The fixing moment at B due to the load $\frac{wL}{2}$ on BF is $M = \frac{wL^2}{48}$ and $M_{CF} = -M$. The fixing moments at F when B and C are considered to be hinged are $-\frac{3M}{2}$ for FB and $\frac{3M}{2}$ for FC. By calculating moments about F, $H_o = -\frac{15M}{2r}$ and acts inwardly.

By distributing the bending moments as shown in *Table* II,

$$hH_1 = -\frac{4M}{15} - \frac{8M}{15}, \quad \text{therefore } H_1 = -\frac{12}{15h} = -H_2, \text{ and } H_2 = 0.$$

$$H_{rafter} = H_o + \tfrac{3}{4}r(M_{BC} - M_{CB}) = -\frac{15M}{2r} + \frac{3}{4r} \times \frac{22M}{15} = -\frac{16M}{15}.$$

The unbalanced force U_1 is $\frac{16M}{15} - \frac{2M}{35} = \frac{106M}{105}$ and acts at B and B_1 (*Fig.* 4*a*).

The balancing force acts in the opposite direction to that shown in *Fig.* 3(*a*), so that

$$H_1 = \frac{2M}{35} + \frac{106M}{105}\left(\frac{4538}{13{,}290} + \frac{24}{167}\right) - \frac{106M}{105}\left(\frac{4538}{13{,}290} - \frac{24}{167}\right) = \frac{58M}{167},$$

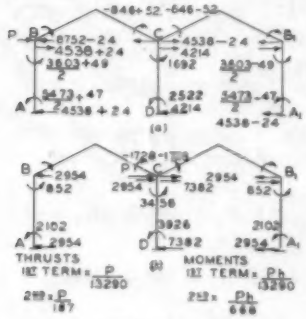


Fig. 3.

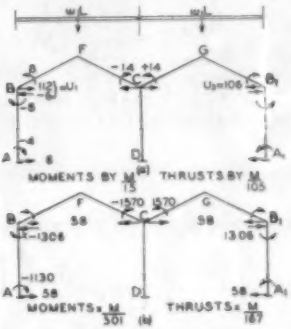


Fig. 4.

TABLE II.

	A	½	B ?	−½	C ?	−½	B ?	½	A_1
			M	−M	M	−M			
	$-\frac{4M}{15}$	$-\frac{8M}{15}$	$\frac{7M}{15}$	$\frac{M}{15}$	$-\frac{M}{15}$	$\frac{7M}{15}$	$\frac{8M}{15}$	$\frac{4M}{15}$	
SUM	$-\frac{4M}{15}$	$-\frac{8M}{15}$	$\frac{8M}{15}$	$-\frac{14M}{15}$	$\frac{14M}{15}$	$-\frac{8M}{15}$	$\frac{8M}{15}$	$\frac{4M}{15}$	

$$M_{AB} = -\frac{4M}{15} - \frac{106Mh}{105}\left(\frac{5473}{26,580} + \frac{47}{668}\right) + \frac{106Mh}{105}\left(\frac{5473}{26,580} - \frac{47}{668}\right) = -\frac{1130M}{501},$$

$$M_{BA} = -\frac{8M}{15} - \frac{106Mh}{105}\left(\frac{3603}{26,580} + \frac{49}{668}\right) + \frac{106Mh}{105}\left(\frac{3603}{26,580} - \frac{49}{668}\right) = -\frac{1306M}{501},$$

$$M_{CF} = -\frac{14M}{15} + \frac{106}{105}\left(\frac{846}{13,290} - \frac{52}{668}\right)Mh - \frac{106Mh}{105}\left(\frac{846}{13,290} + \frac{52}{668}\right) = -\frac{1570M}{501}.$$

H_2, $M_{A_1B_1}$, $M_{B_1A_1}$, and M_{CG} are equal to but of opposite sign to these values and are shown in *Fig.* 4*b*.

By substituting $M = \frac{wL^2}{48}$ the complete solution is obtained.

Double Gable Frame with Hinged Bases.

The bending moments and forces in frames with hinged bases may be solved in a manner similar to those with fixed bases. Side loads of value $\frac{1}{2}P$ of like sign are added to similar side loads of opposing sign for two single frames, and these are combined to form one frame of two bays with a side load P applied at the eaves. By substituting $\frac{1}{2}P$ and $\frac{1}{2}K_2$ for P and K_2 in equations (11) to (14) of the previous article, the following equations are obtained. The stiffness of BA is to the rafter frame BC as $6K_1$ is to 7 and C_1 is to $\frac{3EKA}{h}$; then

$$M_{CD} \times \frac{2\beta_4}{hP} = (6K_1 + 2)\frac{h^2}{rK_1} - 3h. \quad . \quad . \quad . \quad (15)$$

$$\frac{2}{hP} \times \left.\begin{matrix} M_{BA} \\ M_{B_1A_1} \end{matrix}\right\} = \frac{1}{2\beta_4}\left\{4r + 9h + \frac{h^2}{rK_2}(6K_2 + 4)\right\} \pm \left\{\frac{rK_1(7r + 6h)}{Y_1}\right\} \quad . \quad (16)$$

$$\frac{2}{hP} \times \left.\begin{matrix} M_{CB} \\ M_{CB_1} \end{matrix}\right\} = -\frac{1}{2\beta_4}\left\{3h + 6(K_1 + 2)\frac{h^2}{rK_1}\right\} \mp \left\{\frac{r(6K_1h + 6h + 5K_1)}{Y_1}\right\} \quad (17)$$

$$\frac{2}{hP} \times \left.\begin{matrix} C_1 \\ C_3 \end{matrix}\right\} = \frac{1}{2\beta_4}\left\{(7K_1 + 8)r + 12h(K_1 + 1) + \frac{4h^2}{rK_2}(3K_1K_2 + 4K_1 + 2K_2 + 2)\right\} \pm \left\{\frac{r^2hK_1(6K_1 + 7)}{Y_1}\right\}. \quad . \quad (18)$$

$$\frac{2\beta_4}{hP}C_2 = 0{\cdot}5rK_2 + 3h\left(2 + 2K_2 + \frac{K_2}{K_1}\right) + \frac{2h^2}{rK_1}(3K_1K_2 + 4K_1 + 2K_2 + 2) \quad . \quad (19)$$

$$\beta_4 = 2r + 6h + \frac{h^2}{rK_2}\left(6K_2 + \frac{K_2}{K_1} + 2\right). \qquad Y_1 = 12h^2K_1 + 8h^2 + 12rhK_1 + 7r^2K_1.$$

Substituting the values used for the example with columns with fixed bases,

$$M_{CD} = \frac{910hP}{2340}, \quad M_{BA} = \frac{715hP}{2340} + \frac{27hP}{370}, \quad M_{B_1A_1} = \frac{715hP}{2340} - \frac{27hP}{370},$$

$$M_{CB} = -\frac{455hP}{2340} - \frac{522P}{370}, \quad M_{CB_1} = \frac{455hP}{2340} + \frac{522P}{370}, \quad H_2 = \frac{910P}{2340},$$

$$H_1 = \frac{715P}{2340} + \frac{27P}{370}, \quad H_3 = \frac{715P}{2340} - \frac{27P}{370}, \quad C_1 = \frac{2795 \times hP}{2340}.$$

$$C_3 = \frac{3EK_2\Delta_2}{h} = \frac{2795h}{2340} \text{ and } \Delta_3 = \frac{2795h^2P}{10{,}020E}.$$

SIDE LOAD.—As shown in *Fig.* 2, two side loads of $\frac{1}{2}P$ are equivalent to side load P acting at C on the combined frame.

Substituting K_2 for K_1 and K_1 for K_2 in equations (11) to (14) of the previous article dealing with single-gable frames, making M_{AB} into M_{CD} and M_{CD} into $2M_{BA}$, and as $2M_{BA} = 2M_{B_1A_1}$, etc.,

$$2\beta_5\frac{C_2}{hP} = (3{\cdot}5K_2 + 8)r + 6h(K_2 + 2) + \frac{2h^2}{rK_1}(3K_1K_2 + 2K_2 + 4K_1 + 2). \quad (20)$$

$$\frac{4\beta_5}{hP} \times \left.\begin{matrix} C_1 \\ C_3 \end{matrix}\right\} = rK_1 + 6h\left(1 + 2K_1 + \frac{2K_1}{K_2}\right) + \frac{4h^2}{rK_2}(3K_1K_2 + 2K_2 + 4K_1 + 2) \quad (21)$$

$$\frac{4\beta_5}{hP} \times \left.\begin{matrix} M_{BA} \\ M_{B_1A} \end{matrix}\right\} = 2(3K_2 + 2)\frac{h^2}{rK_2} + 3h \quad (22)$$

$$\frac{2\beta_5}{hP}M_{CD} = 4r + 9h + \frac{h^2}{rK_1}(6K_1 + 2) = -\frac{4\beta_5}{hP}M_{CB} = -\frac{4\beta_5}{hP}M_{CB_1} \quad (23)$$

where $\beta_5 = 2r + 6h + \frac{h^2}{rK_1}\left(6K_1 + \frac{2K_1}{K_2} + 1\right)$.

Substituting $K_1 = K_2$, etc., in the equations the following values are obtained.

$$\left.\begin{matrix} M_{BA} \\ M_{B_1A_1} \end{matrix}\right\} = \frac{553hP}{2340};\quad M_{CD} = \frac{1234hP}{2340} = -2M_{CB} = -2M_{CB_1}.$$

$$H_1 = H_3 = \frac{553P}{2340};\quad H_2 = \frac{1234P}{2340};\quad C_2 = \frac{3119hP}{2340};\quad C_1 = C_3 = \frac{2795hP}{2340} = \frac{3EK_1\Delta_1}{h}.$$

Therefore $\Delta_1 = \frac{2795h^2P}{7020E} = \Delta_3$ for P acting at the top of an external column, so that the horizontal deflection at B due to P acting at O.S. is equal to the horizontal deflection at C due to P acting at B.

The values calculated from equations (15) to (17) and equations (18) and (19)

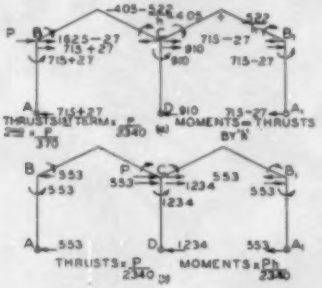


Fig. 5.

are shown in *Fig.* 5. These values can be used as previously demonstrated to calculate moments and thrusts for all other types of loading.

Frames having partially-fixed bases may be calculated in a similar way to that shown for single-bay frames.

Precast Curved Roofs.

In *Figs.* 1, 2, and 3 is shown the erection of a new type of precast curved roof developed by Vacuum Concrete, Inc., of Philadelphia, U.S.A. The roof was cast in halves on the ground, one on top of the other, by the vacuum process. After curing for three days, the half-roofs, each measuring 49 ft. by 20 ft. by 2½ in. thick, were hoisted by a vacuum lifter on to the frames at the ends of the building. The pipe used as a spreader is 10 in. diameter, and also serves as the vacuum chamber. The joint between the two slabs is filled with in-situ concrete. The foregoing is abstracted from " Rock Products " (U.S.A.).

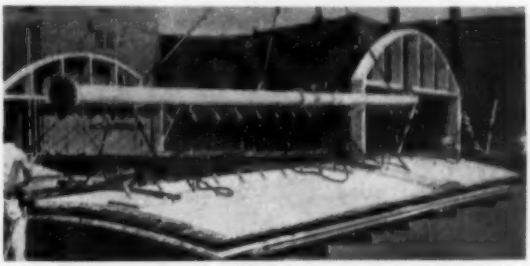


Fig. 1.

Fig. 2.

Fig. 3.

Prestressed Platform Roofs.

THE station at Potters Bar has been completely reconstructed, and the platforms are now covered by prestressed concrete awnings (*Fig.* 1). Each awning is 130 ft. long and about 35 ft. wide, and is supported by two pairs of columns spaced 65 ft. longitudinally and 11 ft. transversely. The slabs are about 4 in. thick and are transversely prestressed. The two longitudinal beams project above the slab (*Fig.* 2). With either the dead weight alone, or with the addition of a uniformly-distributed live load, tensile stresses due to bending occur only at the top, with a maximum above the columns and zero at the ends of the cantilevers and at mid-span. Straight prestressing cables are provided near the top of the stepped beams to compress the upper surface and thus counteract tensile stresses due to bending. Provision has been made for accidental live load not uniformly distributed over the roof.

The slabs were prestressed with cables comprising four wires of 0·276 in. diameter placed in grooves 11 in. apart in the top of the slab. The cables were looped around one end strip of the slab and the two ends of each cable were tensioned at the other end.

The beams are 130 ft. long by 8 in. wide and vary in depth according to the bending moment; the greatest depth is 3 ft. 3 in. at the supports, reducing to 1 ft. 1½ in. at the ends (*Fig.* 2). Near the supports there are four cables one above the other each comprising 24 wires of 0·2 in. diameter. The bottom cable extends over the entire length and the cable above the first is 108 ft. long.

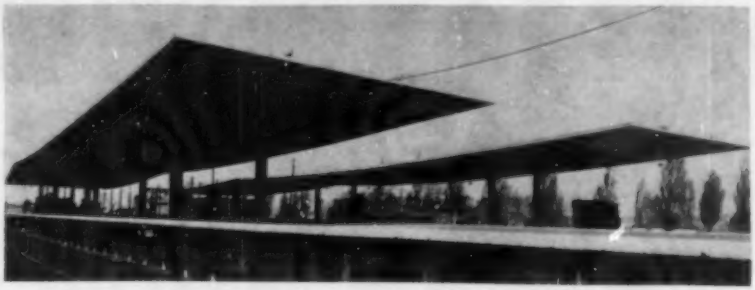


Fig. 1.—Completed Roofs.

Fig. 2.—Top of Roof.

There are two further cables, 27 ft. and 15 ft. 6 in. long, over each column. All the cables are of the Magnel-Blaton type. The cable ducts were pressure grouted, and the cables in grooves along the top surfaces of the steps were covered with cement mortar.

Due to adverse weather and the difficulties caused by working at a busy station, it is considered that it would be preferable in future to employ precast construction at similar sites. The shuttering for the slab was supported as seen in *Fig.* 3; the rakers were provided to allow space for the passengers on the platforms.

The tendency for a downward deflection at the ends, with hogging between the supports, is opposed by the prestressing, the resultant deformation under maximum live load on the cantilevers being still upwards at the ends to ensure satisfactory drainage (the downpipes are at the columns). In this case the deformation is much more pronounced than was anticipated, owing to the fact that the modulus of elasticity of the complete slab was apparently less than was expected as a result of the tests of cubes and prisms used as the basis of design. This relates both to elastic and plastic deformation. The difficulty in compacting the concrete in a thin suspended slab under these conditions demands a rather lower assessment of Young's modulus than is usually the case.

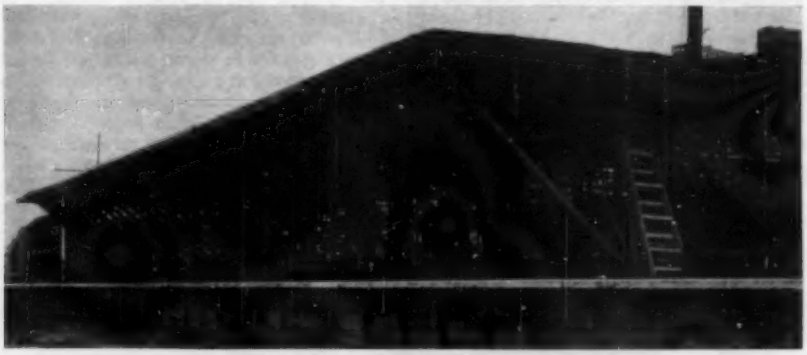


Fig. 3.—Centering for Roof Slab.

The works were commenced under the direction of Mr. J. I. Campbell, M.I.C.E., a former Chief Civil Engineer of the Eastern Region of British Railways, and were completed under the direction of Mr. A. K. Terris, M.I.C.E., the present Chief Civil Engineer of the Eastern Region. The contractors for the civil engineering work were Messrs. M. J. Gleeson (Contractors), Ltd.

Prestressed Concrete Development Group.

At the annual general meeting of the Prestressed Concrete Development Group the following were appointed for the year 1956.

Chairman: Mr. J. Singleton-Green. Vice-Chairman: Mr. G. W. Kirkland, M.B.E.

Committee: Messrs. G. M. Adie, D. A. Andrews, J. Beattie, R. T. Betts, M.B.E., C. F. Brereton, D. M. Chaston, H. G. Cousins, J. Cuerel, R. F. Galbraith, M.C., J. W. Gibson, Gontran Goulden, T.D., C. W. Hamilton, A. J. Harris, E. M. Hayward, R. B. Hill, W. M. Johns, M.C., A. Kirkwood Dodds, M.C., A. Moller and Colonel W. Burrans Sykes, T.D.

Chief technical officer, Mr. A. W. Hill; Secretary, Mr. P. H. T. Gooding. Assistant Secretary, Mr. G. E. Young.

A Multiple-Story Precast Frame Structure.

THE use of factory-made precast concrete units for single-story buildings has been an established method of construction for many years, and the knowledge gained in this class of work has been applied recently to multiple-story buildings. In an extension to the printing works of Messrs. J. Evershed & Co. (Bow), Ltd., at St. Albans, the use of a precast concrete frame followed a suggestion made by the contractors, and was agreed to by the consulting engineers only provided that the protruding brackets and other fittings generally associated with precast concrete frames were omitted. *Fig.* 1 is an interior view.

Fig. 1.—Interior of the Completed Building.

Restricted conditions at the site prevented the use of a crane travelling around the outside of the building, and the erection of all the members for the three stories and the roof had to be done by a mobile crane with a 60-ft. jib that travelled backwards to the entrance to the site (*Fig.* 2).

All the columns, which were about 32 ft. long, were cast in one length, provision being made for seatings for main and secondary precast beams as indicated in *Fig.* 3. The columns were wedged into pockets 1 ft. 6 in. deep in prepared foundations and set plumb ready to receive the beams. The smaller cross section at each floor level necessitated careful handling, and a special cradle was used to support the columns during transport from the works to the site.

As soon as two or three rows of columns were erected the main and secondary beams were delivered and set on the seatings provided at each level. The secondary beams that did not rest on columns were accommodated in slots provided in the sides of the main beams. The columns and beams remained securely in place under their own weight. When the beams were in place, the joints were reinforced and concreted (*Fig.* 4). Provision was made in the beam reinforcement for the attachment of crane slings, thus avoiding additional lifting tackle.

The floor and roof slabs were cast in place in order to ensure a rigid structure to contain heavy machinery and to resist vibration. *Fig.* 3 indicates the method of

Fig. 2.—Members being Erected by a Mobile Crane.

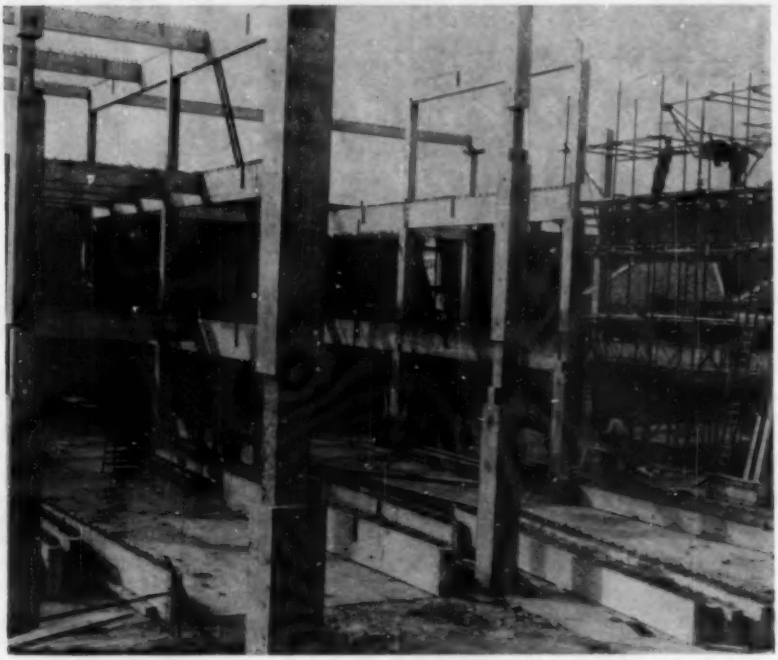


Fig. 3.—Precast Columns with Seatings for Beams.

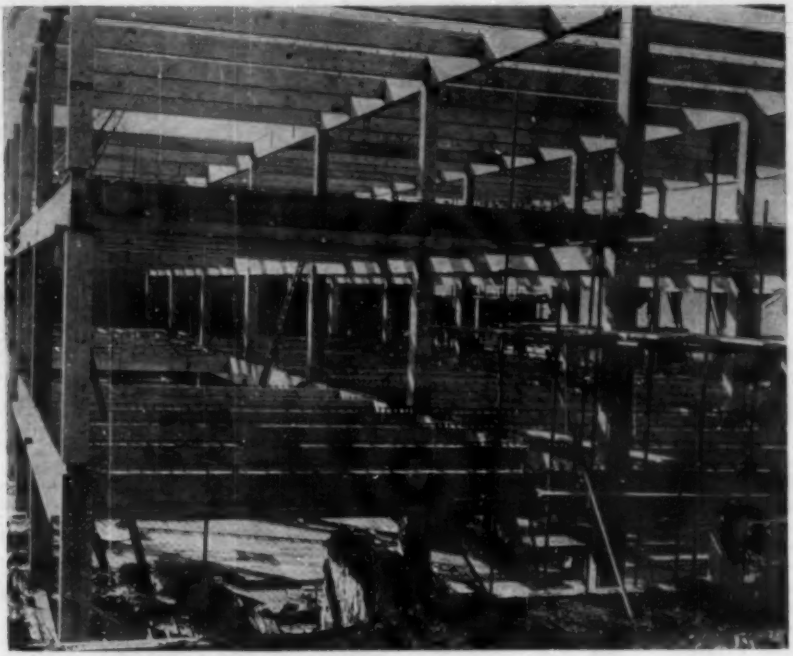


Fig. 4.—Joints Concreted after Erection of Beams.

joining the precast and in-situ work. Holes had been provided in the beams for the suspension of service conduits and plant, and economy in props was effected by making use of these holes in supporting the floor centering.

Fig. 4 shows the complete frame, which was erected in thirteen normal working days by Messrs. Charles R. Price. The Kingsbury Concrete Co., Ltd., supplied all the precast units. Messrs. J. C. Hughes & Partners were the consulting engineers, who collaborated with the contractors in the design of the work. The architects for the complete project were Messrs. E. William Palmer & Partners.

Precast Concrete Air-ducts at Power Station in Poland.

At the power station now in course of construction at Łodź, Poland, seventeen precast hollow concrete piers, 105 ft. high and weighing 92 tons, will form one of the walls of the building and will also serve as air-ducts for the boiler-room. It is claimed that by the use of this type of wall economies are made in time and materials, and that construction will be completed seven months earlier than would otherwise have been the case. The quantity of reinforcement used in this part of the construction is reduced by 70 per cent. due to prefabrication, and steel air ducts will be omitted.

Allt-Na-Lairige Dam.

A photograph of the construction of this dam was given in the advertisement of Messrs. Marples, Ridgway & Partners, Ltd., on p. xlv of our December number, but from the caption the statement that the consulting engineers are Messrs. Babtie, Shaw & Morton was inadvertently omitted.

Book Reviews.

"Analysis of Structures." By M. Smolira. (London: Concrete Publications, Ltd. Price 18s.)

SIMPLIFICATION of the methods of calculating bending moments on statically-indeterminate frames is of considerable importance to designers of reinforced concrete structures, for even if it were desirable economically to ignore the effects of continuity it is impossible in practice not to take account of the monolithic nature of the construction without risking the possibility of undesirable cracking, if not collapse, of a structure. Probably the two most important steps in simplifying these computations were the introduction just before the year 1920 of the slope-deflection method, and about ten years later of the method of moment-distribution. The method described in this book is similar to the method of slope-deflection, but the setting-out of the equations may be carried out more quickly and there is no need for a sign convention; the moments and forces are assumed to act in the directions required to convert the members, first assumed to be statically determinate, into a continuous frame. As every operation can be visualised, the drawing of the deflected form of the structure is a considerable help in setting-out the equations, and there is little likelihood of mistakes being passed over. Designers accustomed to using the moment-distribution method may question the advantages claimed for Mr. Smolira's method, and for continuous beams it is possible that there is little to choose between the methods, but for all problems involving sway, that is for almost every indeterminate structure other than a continuous beam, in which corrections have to be made (usually by the solution of a series of simultaneous equations) to the initial distribution, then the method here described is more direct as all the conditions of the problem are set down at once.

The treatment is so thorough that at a first glance it may appear a little involved, but this is not so. When the principle is mastered the basic equations may be quickly written down for the most complicated structures without the need to memorise any formulæ. Frames with inclined members or members of any shape present few difficulties, and very little work is required to take into account the effect of varying moments of inertia. The generality of the method is illustrated by the examples, of which there are sixty, covering nearly every conceivable case, including the effects due to changes of temperature and settlement of supports.

Vierendeel girders, both simply-supported and continuous, are treated in detail, and include examples of the cases frequently met in practice, but generally ignored in text-books, in which the end panels or the central panels are solid. One questionable point in the treatment is the author's statement that the influence of direct stresses on continuous Vierendeel girders may be ignored; this is not always so.

Some particularly interesting examples are of beams intersecting on plan on a rectangular or diagonal grid. In these structures it is, of course necessary to take account of the torsional rigidity of the beams and its effect on the bending moments. These examples will be of much value to the experienced designer, for little has been published on the subject; and for the junior designer or student the book will be valuable as describing a method which will enable the statically-indeterminate bending moments or forces to be calculated for most of the frames likely to be encountered.—J. E. G.

"Taschenbuch für Bauingenieure." Two vols. Edited by F. Schleicher. (Berlin: Springer Verlag. 1955. Price 56 DM.)

THIS manual of civil engineering, in the German language, contains 35 chapters contributed by various authors. It gives practising engineers most of the information they are likely to require in their work, and it provides students with the fundamental principles. New chapters have been added on hydro-mechanics, building construction, principles of stability, vibrations in structures, and steel structures. The other sections have been revised. There are chapters on impounding dams and hydro-electric work. The books have good illustrations, many numerical examples, and copious references, but there are no tables or design charts; mathematical tables, however, are numerous. In the subjects treated and general arrangement the work is similar to "Civil Engineering Reference Book" by E. H. Probst and J. Comrie published in this country.

A New Method of Underpinning.

An alternative to the usual method of "needling" has been developed by which access to only one side of a wall is required and cutting away is confined to the space required for the beam plus 6 in. to 12 in. above it.

Holes are cut in the wall at about 3 ft. intervals and stools are put in position to replace the support cut away. The wall between the stools is then removed so that the stools support the structure above. Reinforcement for the beam is threaded through openings provided in

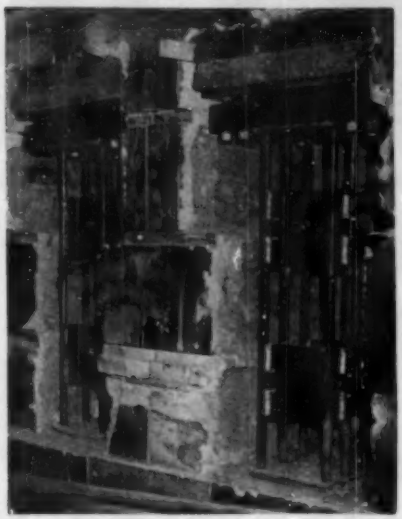


Fig. 1.

the stools, and stirrups are fixed as required. The beam is shuttered and concreted to within a few inches of the underside of the existing wall, and the gap is afterwards packed with stiff concrete to provide a continuous support. The load is transferred only once, the stools remaining as part of the completed beam.

Short stools to carry small loads are of precast concrete, otherwise they are of steel. When the reinforcement bars cannot be threaded into position, special heads are provided on the stools. This method was used at a cinema where the

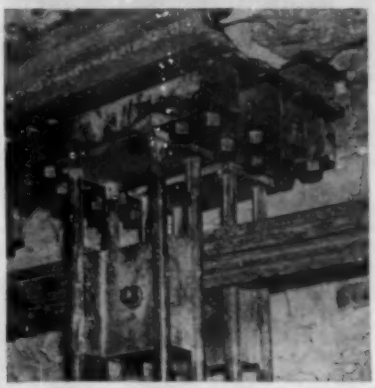


Fig. 2.

lintel over the entrance was curved in plan and was built in at the ends and supported by two intermediate columns. The lintel and columns were to be removed and replaced by a reinforced concrete beam 3 ft. deep by 1 ft. 6 in. wide having a span of 18 ft. and 6 ft. bearing at each end. The work was accessible from the outside only.

The stools had a bottom steel plate to which eight vertical bars were welded, secured together in sets of four with a vertical gap between each set. The bracing comprised short lengths of steel joist to which the vertical bars were welded. The top braces were connected by a spacer-barrel and bolt (*Fig.* 1). On the top of each set of four bars a smaller plate was welded, and on top of these were placed four steel blocks, each drilled

Fig. 3.

Fig. 4.

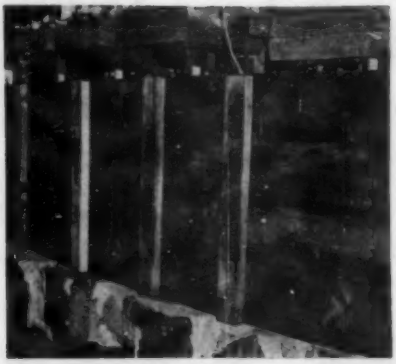


Fig. 5.

and tapped to receive four bolts (*Fig.* 2). The stools were designed to carry the load with any one of these four blocks removed. The ends of the bolts supported a single steel plate covering all four blocks, and on this a concrete pad 3 in. thick was laid. Stiff concrete was packed into the space between this pad and the brickwork above.

When all the stools were in position and the intervening brickwork had been removed the outer steel blocks were taken away and a reinforcement bar laid over the top plates of the stools (*Fig.* 3). The blocks were replaced and the bolts tightened up, with the reinforcement bar between the first and second block. The second row of blocks was then removed and the bar moved between the second and third blocks. In this manner eight bars were passed to the centre and four to the far side beyond the fourth block and were lowered to the required position and supported by U-shaped stirrups. The stools (*Fig.* 4) also served as reinforcement to resist shearing.

The shuttering is shown in *Fig.* 5.

Fig. 6.

The top of the shutter and hence the concrete was below the heads of the stools, and bricks were laid on the concrete to within an inch or two of the underside of the old work. The gaps under the top plates of the stools and the gap remaining above the brickwork were packed with stiff concrete (*Fig.* 6).

The work described was supervised by Mr. Dixon Hurst, A.M.I.Struct.E. The underpinning system (which is patented) was devised and carried out by Pynford, Ltd.

A Stadium in the U.S.A.

THE roof of a sports stadium constructed at the North Carolina State fair ground, Raleigh, North Carolina, consists of two oblique arches of reinforced concrete supporting steel cables, slung between them in the form of a grid, which carry insulated steel decking. The arches, which were described in a recent number of "Engineering News-Record", lie in planes sloping in opposing directions at an angle of about 22 deg. with the horizontal and resist the horizontal pull of the cables, while the vertical loads are carried by slender steel columns encased with concrete (*Fig.* 1).

The thrust of the arches is resisted by concrete abutments in the ground.

Construction of the Abutments and Arches.

One footing and the central section of each tunnel between the footings were cast first (*Fig.* 3). In the tunnels were placed cables which were later tensioned to tie together the footings of the opposing arches.

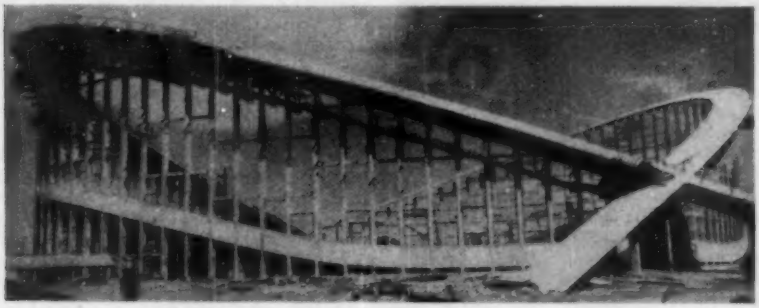


Fig. 1.—The Arches during Construction.

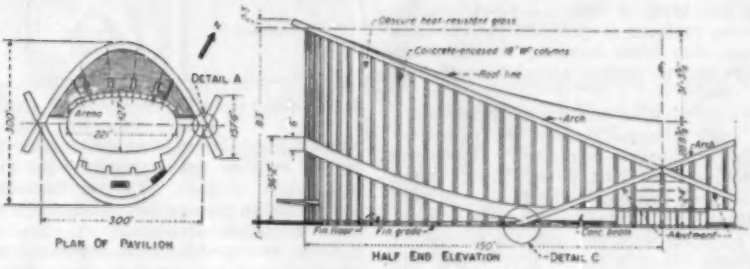


Fig. 2.

The plan and elevation of the stadium are shown in *Fig.* 2. The arches are a parabolic shape on plan. They have a depth in the sloping plane of 14 ft. and a width of 2 ft. 6 in. At the highest point they are 85 ft. above the ground and the two arches intersect at a height of 25 ft.

The stranded cables had sockets at one end only, and the free end was threaded through 4-in. diameter fibre sleeves in the footings, through diaphragms in the tunnels, and through a bearing plate 1 in. thick (*Fig.* 3). The sockets were then attached and the remaining sections of the tunnels and the second footing were cast, including a vault providing space for tensioning the ties. As the building was erected and the load came on the

abutments, the cables were tensioned by 100-tons hydraulic jacks at both ends. The maximum force in each cable is 25 tons.

The abutments were cast next. Each consists of two members that appear to be continuations of the arch ribs. They support the arches at a height of about 25 ft. above the ground. The shutters were made of plastic-coated plywood. A stiff concrete mixture was used to eliminate the need for a top shutter. The concrete was batched on the site and transported to the shutters in truck-mixers. The mixture comprised ¾-in. maximum-size aggregate, 611 lb. of cement per cubic yard, and water to give a slump of 1 in. to 1½ in. The concrete was placed by crane and bucket, and vibrated with rubber-tipped electric vibrators; it had a compressive strength of 4800 lb. per square inch at seven days.

The inclined members of the abutments are recessed at the top to receive a pair of cast-steel hinges that transfer the load from the two opposing arches to each abutment (*Fig.* 4). The hinges prevent the arches from inducing bending moment in the inverted V-shaped supports. They also increase the flexibility of the ribs, thus reducing the effects of variations of temperature.

A thin layer of cork was placed on the bearing surfaces to prevent the concrete of the ribs from bonding to the abutments and to permit a slight rotation of the ribs.

While the abutments were being built, the steel columns around the perimeter of the building were erected. These are wide-flange sections 18 in. deep, which are encased in concrete for fire protection.

Along the line of the intersection of the columns with the stand a reinforced concrete beam, 6 ft. by 1 ft. 6 in., was constructed integrally with the top of the

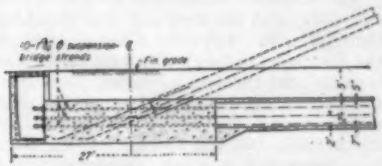
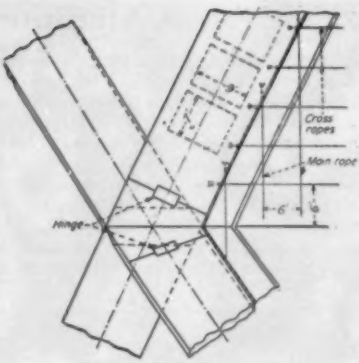


Fig. 3.—Section through Footings (Detail C of Fig. 1).



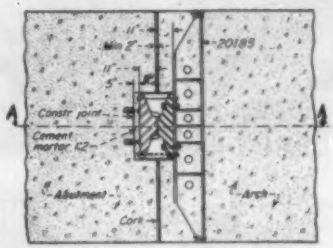


Fig. 4.—Details of Hinge.

stands. This beam rises from near the ground level at the supports of the arch to a height of 36 ft. The reinforcement is continuous, passing through holes in the webs of the steel columns.

After the stands were concreted the columns were concreted to the soffits of the arches. The concrete cover to the columns is thin, and serves to protect continuous wire cages, riveted splices, and struts which frame into the columns at various levels, and had to be placed as high as 84 ft. above the ground. Metal shutters suspended from scaffolds were used. The concrete contained ¾-in. crushed stone aggregate and an air-entraining agent. A sheet-metal chute 4 ft. long clamped to the open top of the column shuttering and with a bifurcated lip to guide the concrete around the

flanges and web of the column was used to place the concrete.

The steel columns were used to support the shutters of the arches. The arches have a trough section (*Fig.* 5) and were also cast in plastic-coated plywood shutters. The main support for the shutters and the catwalks were pairs of steel channels 20 ft. long that were clamped to the tops of the steel columns.

The reinforcement for the ribs was fabricated into cages 40 ft. long on the ground; these were hoisted to the shutters and bent to the curvature of the arch by ratchet hoists and blocks. All laps were welded to prevent displacement of the cages, and the transverse reinforcement at the columns was welded to the tops of the columns and to the longitudinal reinforcement.

The arch was concreted in sections about 60 ft. long, alternately on opposite sides of the building. The concrete was water-cured for seven days before the shutters were stripped. After the first arch had been completed, the second arch was concreted in the same manner.

The Roof.

The cables are spaced 6 ft. apart in two directions at right angles to form a grid which, when covered with the steel deck, forms a doubly-curved surface shaped like a saddle.

Fig. 5.—Cross Section of Arches.

The main cables are galvanised bridge strands, $\frac{3}{4}$ in. to $1\frac{1}{8}$ in. diameter, depending on the span. They were designed for a dead load of 6 lb. per square foot and a live load of 25 lb. per square foot. The cross cables vary from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. diameter. Their purpose is to distribute the load to the main cables and to resist uplift (the roof is designed for an uplift of 16 lb. per square foot). As the cables would lengthen with a rise in temperature and their resistance to uplift be reduced, most of them were tensioned, and guy wires were inserted between the roof and the outer walls to support the cables which were not tensioned.

The structure was designed by Mr. W. H. Deitrick based on the idea of the late M. Nowicki. Messrs. Severud, Elstad & Krueger were the consulting engineers and the general contractors were the Muirhead Construction Co.

Abbreviations.

We have received the following from Mr. Damon Runyan, consulting engineer, of Denver, Colorado, U.S.A.

Considerable interest is being displayed in your Editorial Notes on the use of abbreviations in engineering calculations and literature. Please be advised that the main purpose is to maintain textbooks in the most complete form possible for students and practising engineers. It is well established that much time can be saved and more readable calculations produced by abbreviations which we all know and use throughout the office.

You are quite right in stating that the term "kip" refers to 1000 lb. It might be well to point out that we attempt to keep all our calculations in structural work in terms of feet-kips instead of inch-kips, inasmuch as the terms are smaller and we find it more generally adaptable to our work. In designing large girders and trusses the calculations are more readable and less error is possible in the position of decimal points when feet-kips are used. Our symbols are 'k for foot-kip and "k for inch-kip.

Another item which might interest your readers is our direction to our staff never to write the formulæ used in solving a structural problem, but to enter into the calculations direct. Scrap paper may, however, be used to assure the designer of the derivation of his formula. This is done in order to force the checker to establish in his own mind the formula applicable, or to derive his own. Varied are the results, I can assure you, but it also leads to constructive discussion on proper methods of analysis. This idea is also fostered by Thomas Clark Shedd in his book "Structural Design in Steel", published by John Wiley and Sons, which can be referred to by British engineers for an indication of the use of abbreviations and symbols in the U.S.A.

American Research on Decks of Road Bridges.

RESEARCH on reinforced concrete slabs for road bridges carried out at the University of Illinois during the period 1936 to 1954 is reviewed in a recent Bulletin issued by the University (Volume 52, No. 41, price 25 cents).

The object of this research has been to determine the behaviour of reinforced concrete slabs subjected to vehicle wheel loads and to investigate the effects of the variables encountered in different types of bridge decks. The methods used have included a combination of mathematical analyses as well as extensive tests on scale-model bridges and on full-size elements of bridges.

The method may be summarised as follows. First, analyses were made to establish the variables and to aid in the planning of tests. Next, tests were made on laboratory specimens, usually scale models of highway bridges. And finally, recommendations for design were developed based on the results of the analytical and experimental studies. The design procedures proposed as a result of these investigations are usually made as simple as possible. In some cases they represent merely simplifications of the original analyses, justified by the correlations between theory and tests. In other cases, the procedures are based primarily on the experimental results but are stated in a form derived from or rationally related to the theoretical analyses.

Since ultimate strength was considered to be as important as behaviour at working loads, the problem of determining the maximum load-carrying capacity of reinforced concrete slabs was encountered at almost all stages. In the belief that a clear understanding of the behaviour of beams must precede any attempt to explain the behaviour of slabs, an extensive fundamental study of the ultimate strength of reinforced concrete beams was undertaken.

The report discusses various types of bridges, and gives the following recommendations.

Slab Bridges with Edge-beams.

SQUARE SPAN BRIDGES.—Comparisons of the results of the tests with those predicted by the analyses indicated that the elastic analysis did not provide a suitable basis for design. For one thing, the moments carried by the beams were found to be appreciable, and any design procedure for the beams which neglected their interaction with the slab would lead to cross sections and reinforcement which would be unsatisfactory in service. Moreover, designs based on maximum localised moments in the slab produced structures having load-carrying capacities in terms of live load considerably in excess of those usually desired for highway bridges. The capacities of the test bridges seemed to be more closely related to the average moment across the width of the slab than to the maximum moment.

SKEW SPAN BRIDGES.—Because of the large number of variables encountered in the skew bridges and the limited range of both the analyses and the tests, no generally applicable recommendations for design have been developed on the basis of these studies. It was concluded tentatively, however, that two-line bridges having skews not greater than 45 deg. may be safely designed for moments in the slab and beams corresponding to those in a comparable square bridge, that is a bridge which has a span, width, thickness of slab, and beam details identical with those of the skew bridge, the span in both bridges being measured normal to the supports.

Slab and Girder Bridges.

In highway bridges of the slab-and-girder type, the supporting beams may consist of steel I-beams acting independently, steel I-beams acting compositely with the slab, or concrete beams cast integrally and acting compositely with the slab.

SQUARE SPANS. Recommendations for the design of single-span square I-beam bridges were developed primarily on the basis of the theoretical analysis, since its general validity had been demonstrated by comparison with the test results and since a greater range of variables could be studied analytically than had been considered in the experimental programme. Expressions were developed for the controlling moments in the slab and beams. These expressions included

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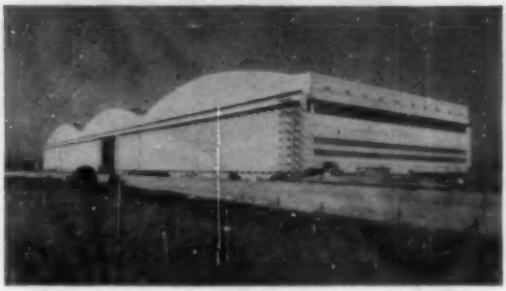

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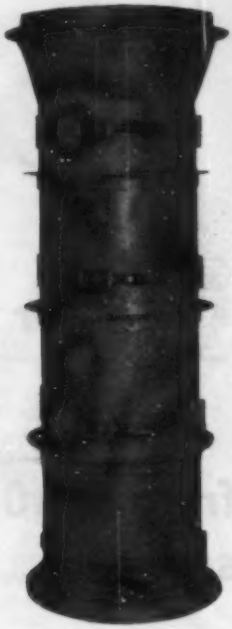

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originally all of the variables known to affect the behaviour and strength of I-beam bridges. However, the number and range of variables were reduced and the equations simplified by making designs for a large number of typical structures under various types of loading and determining the variables.

Continuous Bridges.

The results of analyses and tests indicate that beams for continuous bridges can be designed for the same proportion of a wheel load as that proposed for single-span bridges and that the slab in the regions of positive moment may be similarly designed using the expressions for bending moments recommended for use with single-span bridges. In both cases the span of the single-span bridge used in these calculations should correspond to the portion of the continuous bridge between points of contraflexure. The distribution of moment on the beams may be considered to be the same in regions of positive and negative moment, but in composite bridges the variation in stiffness of the beams must be considered in apportioning the moment to the positive- and negative-moment regions. It has been recommended further that the amount of transverse reinforcement in the top of the slab should be increased in regions over or adjacent to the piers.

Concrete Girder Bridges.

Bridges with concrete girders differ from those with steel I-beams principally in that the stiffness of the beams relative to the slab is much higher. No tests were made of this type of bridge in connection with the investigation of concrete bridge slabs. The analytical studies demonstrated that the behaviour of slab-and-girder bridges with transverse diaphragms is exceedingly complex. Consequently it has not been possible to formulate simple rules for the design of bridges with diaphragms or for the design of the diaphragms themselves. Generally, it can be stated that diaphragms to be most effective must be relatively stiff compared with the beams, and they will have their greatest effects in bridges for which the ratio of beam to slab stiffness is high, namely, in concrete girder bridges. It has been pointed out further that the use of stiff diaphragms may not always prove beneficial insofar as their effect on maximum beam-moments is concerned. For live loads placed on the bridge in such a manner that their centre of gravity is eccentric with respect to the longitudinal centre line of the bridge, the use of stiff diaphragms may increase appreciably the moment on the outside beam on the side of the bridge towards which the loads are shifted.

Courses in Concrete.

So far about four thousand persons have taken advantage of the courses in concrete held by the Cement and Concrete Association at its Training Centre at Wexham Place, near Slough, Buckinghamshire, where hostel accommodation is available for those attending the courses. The courses, which do not exceed one week, are arranged in two groups, one for engineers and one for foremen and other supervisors of work on the site.

The courses for this year are as follows :

Properties of concrete and control of concrete (for engineers), February 20 to 24 ; February 27 to March 2.

Concrete and soil-cement roads (for supervisors), March 19 to 23 ; April 9 to 13.

Soil-cement (for engineers), May 7 to 10 ; May 14 to 17.

Concrete roads (for engineers), September 3 to 7 ; September 17 to 21.

Structural concrete (for engineers), October 1 to 5 ; October 15 to 19 ; October 22 to 26.

Concrete products, October 29 to November 2.

Concrete construction (for builders), November 12 to 16.

Advanced structural concrete (for engineers), November 26 to 30 ; December 10 to 14.

For those requiring accommodation at the hostel the inclusive charges do not exceed £5 for the longest courses. Full details may be had from the Association at 52 Grosvenor Gardens, London, S.W.1.

Contraction Joints in Dams.

THE Pine Tier dam in Tasmania is part of the large hydro-electric scheme at present being carried out. A paper on the design of the dam, by Mr. L. S. Witham, is given in the Journal of the Institution of Engineers, Australia, for April–May, 1955, from which the following note on contraction joints and the control of cracks is abstracted.

The dam is about 640 ft. long at the crest with a central overflow section 400 ft. long. The maximum height is 121 ft. The dam and spillway contain 100,000 cu. yd. of concrete, and this was cast in blocks measuring 30 ft. to 65 ft. across the face (*Fig.* 1). The value of keys on the faces of joints in a gravity dam is problematical, and the fact that they would require the employment of carpenters

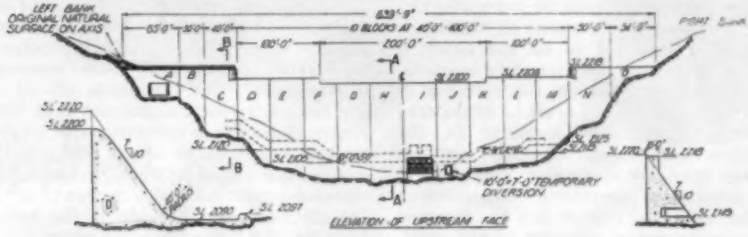

Fig. 1.

favoured their omission; however, as their cost is small compared with the total cost, it was decided to key the joints as an additional precaution against sliding. Standard cantilever shutters with keys measuring 1 ft. 6 in. by 6 in. were available from another dam and were used.

A 32-oz. copper waterstop projecting 5 in. into adjacent blocks is provided across each joint 1 ft. from the upstream face, with "wings" 2 ft. long at every horizontal construction joint. Waterstops are also fitted around the gallery at each joint. A 9-in. diameter drain 1 ft. behind the waterstop leads any leakage either to the gallery or to the downstream face. Removable concrete covers are provided on the crest so that the holes may be cleaned out if necessary. The joints were not grouted. *Fig.* 2 is a section through a typical joint.

With a high rate of concreting, and with concrete containing 445 lb. of cement per cubic yard, the rise of temperature due to the heat of hydration may be as much as 45 deg. F. unless some means of increasing the rate of cooling is used. The method of reducing the possibility of the formation of cracks was as follows.

A modified ("low-heat") cement was used. The specification requirements for heat of hydration and specific surface were that the heat of hydration should not exceed 70 calories per gramme at seven days and 80 calories per gramme at 28 days. The specific surface of the cement as measured by the Pecover-Banks air permeability apparatus was not less than 3300 square centimetres per gramme. The average test results were 61·7 calories per gramme (range 59–64) at seven days, 74 calories per gramme (range 72–76) at 28 days, and the specific surface was 3346 square centimetres per gramme.

Two classes of concrete were used, namely (1) containing 418 lb. of cement per cubic yard and (2) containing 348 lb. of cement per cubic yard; the latter was used for the hearting.

On foundation rock which was substantially level the concrete was placed in half-lifts (2 ft. 6 in.) at minimum intervals of five days until at least 80 per cent. of the foundation rock was covered before 5-ft. lifts were started. Where the side slopes were steep (blocks B, D, M, N,

Fig. 2.

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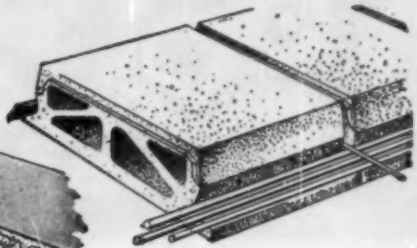
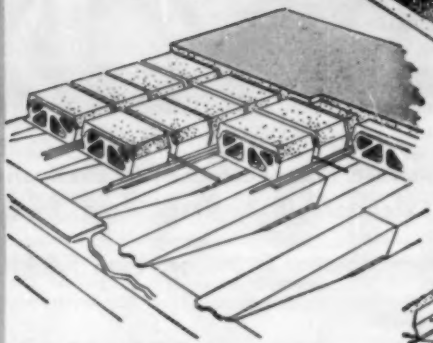
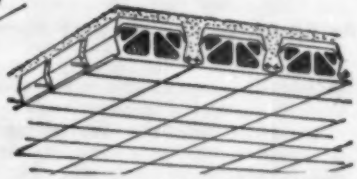
The most adaptable System of Suspended Hollow Concrete Floor and Roof Construction for large and small spans.



Smith's Two-Way Reinforced Floor for distribution of point loads with efficiency and economy.



Showing Two-Way Reinforcement and Hollow Concrete Blocks laid on Trianco Telescopic Centers.



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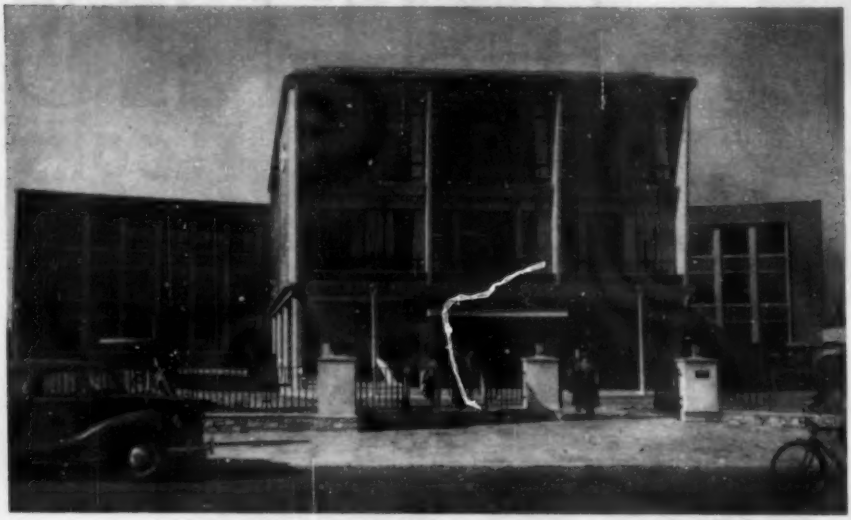

333 Simplex Cast-in-situ Concrete Piles were used in the foundations of the Municipal College Extensions in Anglesey Road, Portsmouth

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where the rises were 32, 35, 33, and 42 ft. in blocks 30, 40, 40, and 50 ft. wide respectively, and block A where the rock rises almost vertically) the concrete was placed in lifts of 2 ft. 6 in. at minimum intervals of five days until the area in plan of rock to be covered by a 5-ft. lift was not greater than 20 per cent. of the area of the top of the preceding lift.

Where the surface of a lift was exposed for fourteen or more days the procedure for placing on rock was followed.

The minimum time permitted between lifts or half lifts was five days.

Cracks in Reinforced Concrete.

THE result of an investigation on the cracking of reinforced concrete beams and slabs is given in the Technical News Bulletin of the National Bureau of Standards (U.S.A) for September 1955. The study included tests on fifty-eight beams and slabs. The beams were of two sizes, namely, 6 in. by 15 in. by 11 ft. tested on a 9-ft. span, and 6 in. by 23 in. by 13 ft. tested on an 11-ft. span. The slabs were 6 in. deep, from 6 in. to 15 in. wide, and 8 ft. long, and were tested on a 6-ft. span. The specimens were simply-supported, and the loads applied at the quarter-points.

The specimens were cast in steel moulds, and all were from the same type of concrete mixture. The tensile reinforcement (deformed bars) was placed near the bottom. Three 6-in. by 12-in. cylinders were cast with each specimen to determine the compressive strength of the concrete; these cylinders were cured and stored in the same manner as the specimens and tested at the same time.

In order to measure every crack within the region of constant bending moment, two rows of strain-gauges were placed at equal distances from the longitudinal centre-line of the specimens. The gauges in the two rows were staggered and overlapped $\frac{1}{2}$ in. Strains in the tensile reinforcement were determined with electrical gauges, and the deflection at the centre of the span was measured with taut-wire scale devices.

To facilitate placing and reading the strain-gauges the specimens were tested in an inverted position. The load was applied in increments ranging from 500 lb. to 5000 lb., and loading proceeded until the specimen failed by yielding of the reinforcement. The positions and extent of the cracks were recorded immediately following each increment of load.

For individual beams the ratio of maximum width of crack to the average width ranged from 1.18 to 2.77. However, the average maximum width of crack was about 1·64 times the average width for each value of stress considered, where the computed stresses in the steel ranged from 15,000 lb. to 40,000 lb. per square inch. Where the computed stress in the steel was 20,000 lb. per square inch the width of the cracks ranged from 0·001 in. to 0·005 in.; at 30,000 lb. per square inch, from 0·002 in. to 0·007 in.; at 40,000 lb. per square inch, 0.004 in. to 0·010 in. The average spacing of cracks decreased rapidly with increase of stress in the steel beyond that causing the first crack, and at a stress of 30,000 lb. per square inch or more the average spacing appeared to approach a constant value. For individual specimens, the minimum average spacing of the cracks varied from 3 in. to nearly 7 in. with an average of 4 in. for all of the specimens.

While the results showed considerable variation, an equation previously derived for symmetrically-reinforced and axially-loaded specimens could be adapted to members subjected to bending. The average width of cracks was proportional to the increase of stress in the steel beyond that causing initial cracking. The average width is also proportional to the product of two parameters $\frac{D}{p}$ and $\frac{(h-d)}{d}$ where D is the diameter of the bar, p the ratio of reinforcement, and h and d are respectively the total and effective depths of the beams. This investigation confirms that the widths of cracks can be reduced by using a large number of small bars and by increasing the ratio of reinforcement.

A New Continuous Batching and Mixing Plant.

A CONCRETE batching and mixing plant with unusual features is shown in *Fig.* 1. This plant has an output of 100 cu. yd. of mixed concrete per day, and similar plants are available with capacities of up to 100 cu. yd. per hour.

On the right of the illustration is the cement silo, from which the cement is delivered to the mixer by means of an inclined screw conveyor. The rate of supply is controlled by varying the speed of rotation of the screw by means of sprockets on the chain-drive from the motor under the silo ; in the larger plants variable-speed gears take the place of the chain mechanism.

The hopper over the mixer is partitioned for coarse and fine aggregate, and delivers to small hoppers immediately below the main hopper. From these smaller hoppers the materials are delivered through adjustable gates to short belt-conveyors. The speed of the belts is constant, and the required quantities are determined by the setting of the gates.

The water measurer is over the end of the mixer and can be set to deliver the required flow of water. A smaller tank is provided for an admixture, and this can also be set to deliver the required amount. The water-control valve also actuates a master contact switch which, simultaneously with the movement of the valve, controls the entire electrical circuit and synchronises the rate of flow of all the materials and liquids. Provision is made for samples of all the materials to be diverted into containers without interrupting the operation of the plant. This enables the accuracy of the measuring devices and the moisture content of the sand to be readily checked. The accuracy of the measurement of coarse aggregate and water is claimed to be within 2 per cent., but frequent tests have to be made for the bulking of the sand if close control is necessary. If greater accuracy is required the machine is fitted with belts on which the aggregates are weighed.

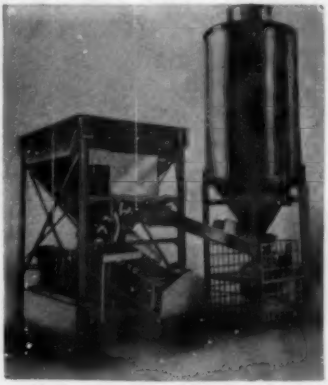

Fig. 1.

The mixer is of the continuous type, and this is recommended because of the lower power consumption and maintenance costs compared with batch mixing. The provision of a control-lever for starting or stopping the plant permits mixing in batches if this is required.

The plant is operated by one man, who stands by the control panel on the left of the illustration and can vary the proportions or consistency at will. By means of a time-switch the machine automatically stops after any desired total quantity of concrete has been produced. The plant is made by Hans Held, of Mannheim, and is sold in this country by Messrs. Baumgarten & Angles.

Protection of Metal Against Corrosion.

A NEW British Standard (No. 2569 : 1955) giving recommendations for the protection of iron and steel against corrosion has been issued in two parts. Part 1 is entitled " Protection of Iron and Steel Against Atmospheric Corrosion," and Part 2 " Protection of Iron and Steel by Aluminium Against Corrosion at Temperatures between 120 deg. C. and 950 deg. C." Each part comprises only four pages, for which the unrealistically high price of 2*s.* is charged.

Some views of the open-air swimming pool at the Skegness Holiday Camp. By kind permission of Messrs. Butlins Ltd.

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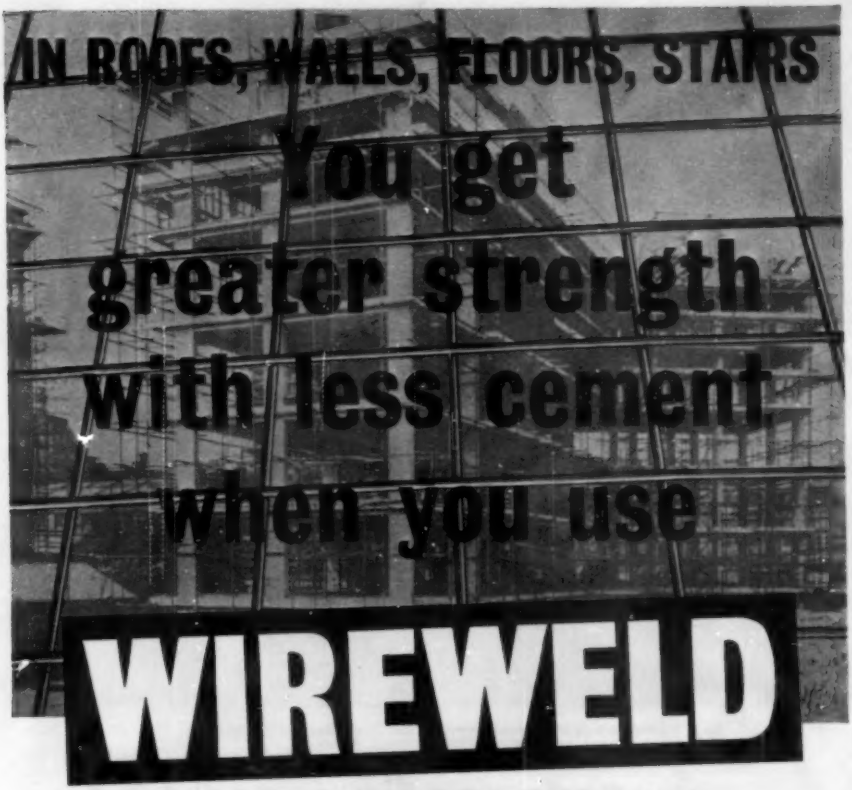

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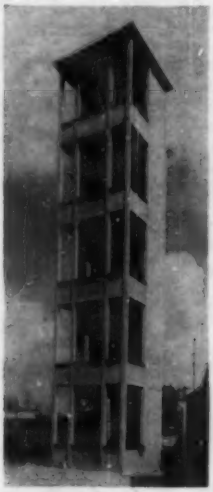
A Precast Fire-Drill Tower.

THE fire-drill tower at Brentwood Fire Station, Essex, shown in the illustration, was designed by A. & C. Buildings, Ltd., Thundersley, Essex, in conjunction with the Essex County Architect. It is 50 ft. high and has nine columns made up with precast concrete units and platforms at intervals.



A reinforced concrete raft carries precast foundation blocks fixed to reinforcement bars projecting from the raft. The precast columns were erected for the first platform and the prestressing cables passed through holes in the columns and the beams of the frame. The precast concrete panels were erected at the same time as the columns.

As the columns for each story were erected they were temporarily prestressed by an external wire of 0·276 in. diameter at each corner of the tower and anchored through the beams. The roof consists of precast panels with an in-situ topping.

Each floor served as a scaffold platform. A mobile hoist was used to lift the concrete units, and when the tower had reached the full height four wires of 0·276 in. diameter in each column were tensioned; these cables are anchored in the foundation blocks. On completion of the tower the temporary wires at the four corners were removed and the remainder of the foundation filled in. The concrete units were made at the works of A. & C. Buildings, Ltd., and transported to the site. The wires were tensioned one at a time with the P.S.C. jack illustrated in this journal for October 1955.

A Machine for Preparing Joints in Concrete Slabs.

THE machine shown in *Fig.* 1 is for preparing joints in concrete runways to receive a sealing compound. Its chief uses are to cut out the top 2 in. of the pre-formed jointing material in new roads and runways and to remove the top 1½ in. to 2 in. of old sealing compound ready for a new one, as may be required to withstand the action of jet engines. The machine can be fitted with four tines of the same or of different widths between ½ in. and 1 in. The tines are adjustable vertically by means of a screw-jack operated by hand from the driver's seat. There is also a wire-brush of 10 in. diameter for cleaning the joint before pouring the sealing compound. The machine is produced by Road Machines (Drayton), Ltd.

Fig. 1.

Lectures on Building.

THE following lectures have been arranged by the Ministry of Works. Admission is free.

Thermal Insulation of Buildings, by W. S. Brydon. College of Further Education, William Street, Slough. February 14. 7 p.m. Also by F. King, Shire Hall, Cardiff, February 14, 7 p.m.

Dampness in Buildings, by J. P. Latham. College of Technology, Byrom Street, Liverpool. February 15. 7.15 p.m.

Arbitration in Building Disputes, by Norman P. Greig. Library, Abington, Northampton. February 15. 7.15 p.m.

Introduction to Prestressed Concrete, by R. C. Blyth. Library, Vernon Road, Scarborough. February 15. 7.15 p.m.

Thermal Insulation of Building Structures, by J. S. Alton. Technical College, 159 Tadcaster Road, York. February 15. 7.15 p.m. Also at Schofield Technical College, Park Road, Mexborough, February 16, 7 p.m.

Powered Hand Tools, by A. F. Coare. East Ham Technical College, London, E.6. February 16. 7 p.m.

Programming of Building Contracts, by H. F. Broughton. Lion Hotel, Petty Cury, Cambridge. February 20. 7.30 p.m.

Safety in the Building Industry, by J. A. Hayward. Technical College, Gloucester. February 20. 7 p.m.

Prestressed Concrete, by F. Walley. Technical College, Bolton. February 22. 7.15 p.m.

Building Contracts, by Norman P. Greig. Castle Hotel, Taunton. February 22. 7 p.m.

Lightweight Concrete, by J. C. Blenkinsop. Gas Showrooms, Osborne Street, Grimsby. February 22. 7.15 p.m. Also by W. Kinniburgh, College of Technology, Howard Street, Rotherham, February 29, 7.15 p.m.

Soil Mechanics, by M. W. Leonard. Technical College, Gladstone Road, London, S.W.19. February 22. 7.15 p.m.

Legal Obligations of Building Contractors, by John J. Clarke. Technical College, Wolfruna Street, Wolverhampton. February 22. 7.15 p.m. Also at College of Technology and Commerce, Beechwood Avenue, Boscombe, February 29, 7 p.m.

Essentials of Good Concreting, by E. E. H. Bate. Technical College, Cauldon Place, Stoke-on-Trent. February 23. 7.15 p.m.

Thermal Insulation, by J. A. Godfrey. Technical College, Palatine Road, Blackpool. February 27. 7.15 p.m. Also at Technical College, Queen Street South, Huddersfield, February 28, 7 p.m.

Plastering and Rendering, by L. A. Ragsdale. Technical College, Broadway, Dudley. February 29. 7.15 p.m.

Reducing the Noise of Pile Driving.

A METHOD of reducing the noise of a steam-hammer during pile driving has been devised by Sir Robert McAlpine & Sons, Ltd., and is shown in the accompanying illustration. The sound-absorbent skirt mounted on the hammer comprises two layers of asbestos-cloth padded with glass-wool. The skirt is attached to a steel belt which is strapped round the hammer. It is stated that the skirt absorbed about 80 per cent. of the sound energy and halved the apparent loudness of the noise.

MISCELLANEOUS ADVERTISEMENTS.

Situations Wanted, 3d. a word : minimum, 7s. 6d. Situations Vacant, 4d. a word : minimum, 10s. Other miscellaneous advertisements, 4d. a word : 10s. minimum. Displayed advertisements, 30s. per column inch. Box number 1s. extra. The engagement of persons answering these advertisements is subject to the Notification of Vacancies Order, 1952.

Advertisements must reach this office by the 23rd of the month preceding publication.

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SITUATIONS VACANT. Senior reinforced concrete designers wanted by leading reinforced concrete engineers and contractors. Must be fully conversant with Code of Practice, L.C.C. Bye-Laws, and able to design light-framed structures from estimating stage to final details. Five-days' week. Pension scheme. Progressive position. Starting salary from £900 upwards according to ability. This year's holiday arrangements honoured. Juniors also required, similar conditions. Write BOX 4172, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

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SITUATIONS VACANT. Assistant structural engineers required with experience of reinforced concrete design. Experience of precast techniques advantageous. Salary according to experience and qualifications. Apply in writing to TECHNICAL MANAGER, THE SCOTTISH CONSTRUCTION CO., LTD., Sighthill Industrial Estate, Edinburgh.

SITUATION VACANT. Reinforced concrete design engineer required by specialist reinforcement designer/suppliers. A.M.I.Struct.E. essential, preferably with constructional experience. Permanent superannuated position with scope for advancement. Write or telephone ROM RIVER CO., LTD., St. Richard's House, Eversholt Street, London, N.W.1. Euston 7814.

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SITUATION VACANT. Reinforced concrete detailer required for consulting engineer's office. Interesting work in all types of concrete framed buildings. Good experience and draughtsmanship essential. Apply in writing, giving details of experience, age, etc., to F. J. SAMUELY, 8 Hamilton Place, London, W.1.

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SITUATIONS VACANT. R. L. BOURQUI & PARTNERS, Thermix House, Kingston-upon-Thames, require a first-class detailer-draughtsman for reinforced concrete work. Applicants must have a fair knowledge of reinforced concrete design and be first-class draughtsmen. Very good opportunity to improve design experience and, if suitable, to secure a further senior position in growing firm. Full summer holiday, etc.

SITUATION VACANT. Assistant civil engineer, particularly with some dock and harbour experience, either site or design, required by professional firm in Westminster. Variety of work is extensive and scope offers attractions to engineer desiring to concentrate on design side. A.M.I.C.E. standard advantageous. Salary from £750 upwards according to experience and qualifications. BOX 4230, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

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(Continued on next page.)

MISCELLANEOUS ADVERTISEMENTS.

(Continued from page lix.)

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SITUATIONS VACANT. Required to take charge of provincial branch office of civil engineers, a qualified engineer (B.Sc., A.M.I.C.E. or A.M.I.Struct.E.). Minimum age 35. Good opportunity for man of strong character, initiative, and drive. Experienced in reinforced, prestressed and precast concrete, structural steelwork, specifications, etc., and general civil engineering design and detail. Salary commensurate with responsibilities, experience and ability. Vacancies also exist for designer-detailers in this and London office. Send full particulars, and salary required, to Box 4232, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Consulting engineers, Westminster, require senior assistant with considerable experience in road and bridge design. High salary and good prospects for suitable applicant. Write in confidence, stating age, qualifications and full details of experience, to Box 4233, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Civil engineering draughtsman, experienced in road and bridge work, required by consulting engineers, Westminster. High salary and good prospects. Write, stating age and details of experience. Box 4234, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

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SITUATIONS VACANT. Reinforced concrete engineers require experienced draughtsman, also juniors, at their head office in Watford. Write, stating age, experience, and salary requirements, to Holst & Co., Ltd., 46 Clarendon Road, Watford.

SITUATIONS VACANT. Reinforced concrete designers with good theoretical knowledge and experience in industrial design required by civil engineers and contractors in Westminster. Good prospects in expanding business. Pension scheme. Staff canteen. Apply in writing, stating age, qualifications, experience, salary required, to Tileman & Co., Ltd., Romney House, Tufton Street, London, S.W.1.

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SITUATION VACANT. Junior civil engineering assistant required in London office. Must be studying for professional qualification. Experience of reinforced concrete design and detailing desirable, but not essential. Good salary, working conditions and prospects. Profit-sharing scheme. Canteen on premises. Write to the Chief Engineer, The Associated Portland Cement Manufacturers, Ltd., Portland House, Tothill Street, London, S.W.1, giving age, experience and training.

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Applicants should be Chartered Structural Engineers and have had experience in steelwork and/or reinforced concrete and be capable of examining designs in accordance with British Standards and Codes of Practice.

Applications will also be considered from GRADUATE MEMBERS of the Institution of Structural Engineers. Salary: £595 to £675 per annum (A.P.T. Grade II), to be increased to A.P.T. Grades IV/V on election as Associate Members.

Application forms obtainable from the City Building Surveyor, Municipal Buildings, Liverpool, 2, should be returned to him, accompanied by copies of not more than three recent testimonials.

The appointments are superannuable and subject to the Standing Orders of the City Council. Canvassing disqualifies.

THOMAS ALKER,
Town Clerk.

Municipal Buildings,
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CIVIL ENGINEERS

Simon-Carves Ltd.

require two civil engineers age about 25. The work will include test boring on sites and soil tests in the laboratory. Applicants should be graduates, or at least of H.N.C. level, and must have had training in soil mechanics and site investigation. The posts are permanent and offer good scope. Working conditions are good and a Pension Scheme is in operation. Write, quoting ref. XQ 43, to Staff and Training Division, Simon-Carves Ltd., Cheadle Heath, Stockport.

SITUATIONS VACANT. Reinforced concrete draughtsmen with experience in detailing industrial structures required by civil engineers and contractors in Westminster. Good prospects in expanding business. Pension scheme. Staff canteen. Apply in writing, stating age, experience, salary required, to TILEMAN & CO., LTD., Romney House, Tufton Street, London, S.W.1.

SITUATION VACANT. Consulting engineers, Westminster, require assistant experienced in the design and/or detailing of reinforced concrete bridges. High salary, interesting work and excellent prospects. Write stating age qualifications, and full details of experience. BOX 4235, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATIONS VACANT. Structural designer/draughtsmen, experienced in reinforced concrete and/or structural steelwork, with initiative, who see little scope for the use of this at present, are invited to contact the CONISTON CO., Eagle House, High Street, Wimbledon, London, S.W.19 (Wimbledon 8521), for an appointment to discuss interesting and permanent work in congenial surroundings with a young and progressive company.

SITUATION VACANT. Young civil engineer required as assistant to resident engineer on large sea defence contract in Sussex. Total emoluments £600 per annum. Excellent prospects for suitable man. Apply LEWIS AND DUVIVIER, 122 Victoria Street, London, S.W.1. Victoria 9127.

SITUATION VACANT. Assistant civil engineer, age 26–32, required for consulting engineers' office. Work chiefly maritime, comprising design, estimating, bills of quantities, specifications, also surveys and inspection. Good salary according to experience. Superannuation scheme, excellent prospects. Apply LEWIS AND DUVIVIER, 122 Victoria Street, London, S.W.1. Victoria 9127.

SITUATIONS VACANT. Air Ministry Works Designs Branch require in London structural engineering designer/draughtsmen for reinforced concrete or structural steelwork, with sound technical training and several years' varied experience in design/detailing of (a) Reinforced concrete construction for all types of buildings, or (b) Steel framed sheds, warehouses and similar buildings. Salaries up to £850 per annum. Starting pay based on age, qualifications and experience. Paid overtime. Long-term possibilities with promotion and pensionable prospects. Natural born British subjects. Write, stating age, qualifications, employment details, including type of work done, to any Employment Exchange, quoting Order No. Borough 2304.

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SITUATION VACANT. Reinforced concrete detailer, preferably with some knowledge of structural steel, required at once by City of London consulting engineers. Good salary for suitable man, age about 25–30. Apply J. L. WHEELER & JUPP, Empire House, St. Martins Le Grand, London, E.C.1.

SITUATIONS VACANT. Reinforced concrete detailers required for London office. Previous experience in similar capacity necessary. Attractive conditions of employment. Apply in writing, giving brief particulars of education, experience, age, and quoting L.126, to BRAITHWAITE & CO. ENGINEERS, LTD., 14–16 Regent Street, London, S.W.1.

SITUATION VACANT. Assistant structural or civil engineer required for consulting engineer's office, Sutton/Wallington area. Interesting and varied work throughout the country. BOX 4236, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

LONDON COUNTY COUNCIL

Vacancies in the Structural Engineering Division for Resident Engineers (salary up to £945). Candidates should have B.Sc., A.M.I.C.E., or A.M.I.Struct.E., preferably with experience in supervision of reinforced concrete and/or steel-frame structures on the site, although those with adequate knowledge and experience of design alone will also be considered. Application forms, returnable by 20th March, from ARCHITECT, (AR/EK/RE/4), The County Hall, S.E.1. (108)

SURVEYORS FOR OVERSEAS

Topographical Surveyors required for mapping and layout of roads in Persia in connection with a large road reconstruction project. Both senior Surveyors able to take charge of survey teams and assistant Surveyors to work in survey teams required. Single men preferred. Good salaries offered, plus local allowances. Tour of duty two years with good prospects of renewal. Apply JOHN MOWLEM & CO. LTD., 123 Victoria Street, London, S.W.1.

SITUATION VACANT. Resident engineer required for reinforced concrete viaduct in London area. Must be qualified and have first-class experience of reinforced concrete work and good-quality concrete. Knowledge of road work advantageous. Salary £1,400 per annum. Apply HOWARD HUMPHREYS & SONS, Consulting Engineers, Victoria Station House, Westminster, quoting reference 358.

SITUATION VACANT. Senior structural design assistant required by Westminster consultants. Considerable experience in prestressed and post-tensioned work advantageous. Salary not quoted as it will be based on experience and qualifications of the selected applicant. Post is permanent and carries staff pension. BOX 4241, CONCRETE AND CONSTRUCTIONAL ENGINEERING, 14 Dartmouth Street, London, S.W.1.

SITUATION VACANT. Civil engineer required by an Australian Company operating in Melbourne, Victoria, Australia. Qualifications: University degree; preferably with experience in concrete construction including prestressed work. Salary: Commencing at £A1,700 per annum, and increasing with the development of the company's projects under his supervision. Duties: To be responsible for the design and development of heavy precast units for all types of construction, embracing reinforced and prestressed concrete. Arrangements for successful applicant to come to Australia to be a matter of negotiation between both parties. Applicants should apply in writing stating age, qualifications, and experience, with copies of references, to "CONCRETE," c/o KENT, BRIERLEY & FISHER, 515 Collins Street, Melbourne, Australia. Applications strictly confidential. Closing date 15 March, 1956.

(*Continued on next page.*)

MISCELLANEOUS ADVERTISEMENTS.

(*Continued from page lxi.*)

SITUATIONS VACANT. Senior designer-detailers required for London office of consulting engineers. Considerable experience in reinforced concrete work essential. Five-days' week, pension scheme, luncheon and sports clubs. Apply in writing, with full particulars of age, experience, and salary required, to RENDEL, PALMER & TRITTON, 123 Victoria Street, London, S.W.1.

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PARTNERSHIP.

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FOR SALE.

FOR SALE. New steel gutters, 18 in. × 6 in. × 1/8 in. Cheap prices. Other sizes available. Details on request. E. STEPHENS & SON LTD., Bath Street, London, E.C.1. Clerkenwell 1731.

FOR SALE. Good second-hand steel tubes and fittings for sale. All sizes up to 10 in. nominal bore. E. STEPHENS & SON, LTD., Bath Street, London, E.C.1. Clerkenwell 1731.

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175 tons—NEW, Prime Continental M.S. Reinforcing Rods
35 tons ½-in. dia. × approx. 37 ft. 0 in. Plain
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10 tons ½-in. dia. × approx. 13–14 ft. Ribbed
25 tons ½-in. dia. × approx. 13 ft. Ribbed
5 tons ⅜-in. dia. × approx. 12–14 ft. Plain

Enquiries to:

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Tel.: Elgar 5811

FOR HIRE.

FOR HIRE. Lattice steel erection masts (light and heavy), 30 ft. to 150 ft. high, for immediate hire. BELLMAN'S, 21 Hobart House, Grosvenor Place, London, S.W.1.

DATA FOR PRICING REINFORCED CONCRETE.

Materials.

(*Delivered in London area.*)

AGGREGATES (per cu. yd.).—Washed sand, 25*s.* 1*d.* Clean shingle: ¾ in., 21*s.* 5*d.*; ¼ in., 24*s.* Pit ballast, 24*s.* 6*d.*

CEMENT (per ton, delivered at Charing Cross).—Portland cement, 6 tons and upwards, 101*s.* 6*d.* 1 ton to 6 tons, 113*s.* 6*d.* Paper bags and non-returnable jute sacks included.
Rapid-hardening Portland, 10*s.* 6*d.* above ordinary Portland.
Aquacrete and 417, 32*s.* 6*d.* above ordinary Portland; paper bags included.
Colorcrete (buff, red, and khaki), in 6-ton loads, 158*s.*; paper bags included.
Snowcrete, 262*s.*, inc. paper bags.
"Super-Cement," 32*s.* 6*d.* per ton above ordinary Portland cement; paper bags included.
High-alumina cement: per ton, 307*s.*; 2 tons, at 296*s.* 9*d.*; 4 tons, at 291*s.* 9*d.*; 6 tons, at 288*s.* 3*d.*
Snowcem paint, 71*s.* per cwt. including containers.

SHUTTERING.—1" and 1½" deal sawn shuttering boards, £95–£100 per standard.

REINFORCEMENT.—Mild steel bars, B.S. 785 (per cwt.); ¼ in. to 2½ in., 45*s.* 9*d.*; ⅛ in. to ¼ in., 47*s.* 6*d.*; ⅝ in., 48*s.* 3*d.*; ½ in., 49*s.* 9*d.*

Materials and Labour.

(*Contracts up to £5000. Including 10 per cent. profit.*)

PORTLAND CEMENT CONCRETE, 1 : 2 : 4.—
Foundations, 2*s.* 7½*d.* per cu. ft. Columns, 3*s.* 6½*d.* per cu. ft. Beams, 3*s.* 3½*d.* per cu. ft. Floor slabs, 4 in. thick, 9*s.* 4½*d.* per sq. yd.; Do., 5 in., 11*s.* 10*d.*; Do., 6 in., 13*s.* 6*d.*; Do., 7 in., 15*s.* 10½*d.* Walls 6 in. thick, 15*s.* per sq. yd. Add for hoisting above ground level, 3*s.* 9½*d.* per cu. yd. Add for rapid-hardening Portland cement, 3*s.* per cu. yd.

REINFORCEMENT.—Mild steel bars (B.S. 785), including cutting, bending, fixing, and wire (per cwt.)—¼ in. to ⅝ in., 79*s.* 3*d.* ⅛ in. to ¼ in., 72*s.* 10*d.* ⅛ in. to 2½ in., 66*s.* 10*d.*

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Walls, 214*s.* 2*d.* per square.
Floors (average 10 ft. high), 198*s.* 6*d.* per square. In small quantities, 2*s.* 7½*d.* per sq. ft.
Columns, average 18 in. by 18 in. (per sq. ft.), 3*s.*; in narrow widths, 3*s.* 10*d.*
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Raking, cutting, and waste, 6½*d.* per lin. ft.
Labour on splays, 3½*d.* per lin. ft.
Small fillets to form chamfers, 6½*d.* per lin. ft.

Wages.

The rate of wages on which the above prices are based are: Carpenters and joiners, 4*s.* 1½*d.* per hour (carpenters 2*d.* a day tool money); Labourers, 3*s.* 7*d.*; Men on mixers and hoists, 3*s.* 10*d.*; Bar-benders, 3*s.* 10½*d.*

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